At ovulation, the ovum or egg is collected by the fundibular end of the oviduct or fallopian tube. It is transported down the oviduct towards the uterus possibly by a combination of ciliary (hair-like) action and muscular contractions. Transport through the oviduct appears to be under the control of ovarian steroid hormones since oestrogens reduce and progesterone increases the speed of passage of ova through the oviducts. Fertilization normally occurs in the ampulla section of the oviduct close to the junction with the isthmus. In the cow, the ovum enters the uterus 4–5 days after ovulation. Mammalian spermatozoa acquire motility, and part of their capacity to fertilize the ovum, during their passage through the epididymis. At the same time, they undergo changes in metabolic patterns, enzymatic activities, and the ability to bind to zona pellucida surface, electrophoretic properties, and stabilization of some sperm structures. However, before spermatozoa are able to fertilize the ovum, they have to undergo a further series of maturational changes in the female tract. These processes are known as capacitation and the acrosome reaction and are thought to require about six hours in the cow. This requirement for maturational changes is the main reason why it is preferable to inseminate cows several hours before ovulation. The precise changes involved in capacitation are not fully understood, but they involve enzymic and structural modifications to the acrosome and anterior part of the sperm head membrane. These include:

1. an increase in membrane permeability to calcium
2. modification of the membrane structure
3. activation of the enzyme adenyl cyclase
4. conversion of the protein proacrosin to acrosin.

The process of capacitation is stimulated when sperm enter the female reproductive tract. The acrosome reaction follows capacitation and involves the fusion of the sperm cell membrane and the acrosome and the formation of gaps through which the acrosome contents can diffuse. The acrosome reaction is necessary to allow penetration of the oocyte by the sperm. Capacitation and the acrosome reaction are very closely linked and therefore it is not always possible to distinguish between the two processes. The presence of ovarian follicular fluid and the cumulus oophorus have a stimulatory effect on the acrosome reaction but do not appear to be essential for it.

**Spermatozoa transport**

In the case of natural service, semen is deposited in the anterior vagina whereas with artificial insemination it is usual to place it just inside the uterus or in the anterior cervix. Spermatozoa ascend the female tract by both active and passive processes. Active transport involves activity of the sperm tail or flagella, but clearly, its interaction with epithelial surface secretions and cilia is also important. Propulsion of spermatozoa through the uterus
appears to be quite rapid and the isthmus of the oviduct acts as a spermatozoa reservoir in many species. Recent observations using ultrasound techniques have demonstrated the capacity of the uterus to transport fluids to the vicinity of the oviduct in a matter of minutes, but not all observations have shown this consistently. Spermatozoa have been detected in the oviducts as little as two minutes after insemination.

The fusion of the sperm and ovum cell membranes begins at the middle of the sperm head region. The sperm head becomes engulfed by the ovum with the loss of the tail. The sperm’s nuclear membrane disappears and the male chromatin comes into contact with the ova cytoplasm. Penetration by the fertilizing sperm (pronucleus) stimulates the resumption of the second meiotic division of the oocyte and the extrusion of the second polar body. Fertilization is completed with the fusion of the haploid male and female pronuclei, a process known as syngamy.

**Early development of the embryo**

Gestation is often divided into three stages:

1. The ovum from 0–13 days.
2. The embryo from 14 days, when germ layers (see below) begins to form until 45 days.
3. The fetus from 46 days until parturition.

The ovum begins to divide mitotically, a process known as cleavage, immediately after fertilization is complete. Division continues so that a solid cluster of cells or blastomeres known as a morula (mulberry shape) is formed by five or six days. From about day 6 after fertilization, the ovum begins to hollow out to become a blastocyst. This consists of a single spherical layer of cells, the trophoblast, with a hollow centre, but also with a group of cells, the inner cell mass at one edge. The inner cell mass is destined to form the embryo, whilst the trophoblast provides it with nutrients. At about day 8 the zona pellucida begins to fragment and the blastocyst ‘hatches’. This is then followed by a period of blastocyst elongation. Development of the so-called germ layers begins from about the fourteenth day and characterizes the beginning of the embryo phase. The three germ layers arise from the inner cell mass and are termed the ectoderm, mesoderm and endoderm. The ectoderm gives rise to the external structures such as skin, hair, hooves and mammary glands and the nervous system. The heart, muscles and bones are eventually formed
from the mesoderm whereas the other internal organs are derived from the endoderm layer. By day 16, the embryo is sufficiently developed to signal its presence to the maternal system and prevent the luteolysis that would have occurred if the cow had not been pregnant.

**Formation of the extra-embryonic membranes**

The embryo is able to exist for a short time by absorbing nutrients from its own tissues and from the uterine fluids, but it ultimately becomes entirely dependent on its mother for sustenance. Therefore, the embryo becomes attached to the endometrium by means of its membranes, through which nutrients and metabolites are transferred from mother to fetus and vice versa. The attachment process is known as implantation and may begin as early as day 20, although definitive placentation does not occur until day 40–45.

*The yolk sac*

This structure serves to transfer nutritive material from the uterus to the embryo and is only of transitory importance in mammals. It is formed as an outpouching of the developing gut. It is separated from the uterine wall only by the outer layer of the blastocyst and its blood vessels readily absorb nutrients. The function of the yolk sac is eventually taken over by the allantois.

*The amnion*

This membrane is composed of a layer of mesoderm and a layer of ectoderm, which grow up and over the embryo and eventually fuse to enclose it in a complete sac. The amnion is usually complete by day 18 and becomes filled with fluid, providing support and protection for the developing embryo. The amniotic sac is the so-called water bag that is often seen protruding from the vulva during first-stage labour.

*The allantois*

The allantois is formed as an outpouching of the developing hindgut. This grows outward, eventually coming into contact with the external layer of cells, the trophoblast, to form the chorion or chorion + allantois. This membrane is usually well developed by day 23 and eventually surrounds the embryo, amnion and allantoic cavity, becoming densely vascularized, with the vessels branching away from the umbilical cord.

*Placenta*

The placenta is formed by intimate contact between the chorion and the endometrium. In ruminant species, the placenta is described as ‘cotyledonary’ since placental attachment occurs only in the discrete areas of the endometrial caruncles. Exchange of oxygen, carbon dioxide and nutrients between embryo and mother takes place solely through the cotyledons. By day 32 of pregnancy the allantois and trophoderm almost fill the pregnant uterine horn and fragile cotyledonary attachment is also taking place there. A 12-week fetus and its associated membranes. At the end of gestation the amniotic and allantoic cavities, contain approximately 25 and 15 litres of fluids respectively.
Endometrial cups of the mare:

Attachment of the embryos commences 35 to 40 days after ovulation, and gestation lasts approximately 340 days. Similar to the porcine placenta, the equine placenta is non-deciduate, diffuses, and epitheliochorial. However, the equine chorioallantoic membrane is comprised of villi that associate with maternal crypts. While the entire chorion is modified for exchange, fetal and uterine tissues interact in certain discrete areas termed microcotyledons (microplacentomes or microcaruncules). Placentomes of ruminant placentae can be visualized grossly whereas microcotyledons of the equine placenta can only be identified microscopically. Each microcotyledon is invested with one areola, where the uterine gland secretions collect to nourish the fetus. Endometrial cups are a specialized feature of equine placentae. This term is a misnomer because these cells are of fetal (chorionic) rather than maternal origin. Portions of the chorionic epithelium detach from the chorion at about day 30 to day 35 of gestation. These chorionic cells then colonize and embed within the endometrium. The resulting endometrial cups elaborate equine chorionic gonadotrophin (eCG), which is also called pregnant mare serum gonadotrophin (PMSG). Equine chorionic gonadotropin is identical in amino acid sequence to pituitary LH, and thus, stimulates additional ovarian follicular development. The resulting follicles produce high concentrations of estrogen (equillin). An interesting side note: estrogen-like compounds have been touted for various uses in humans, and therefore brood mare farms have been created to collect this estrogen-enriched urine from pregnant mares and purify it for use in humans. The additional ovarian follicles eventually undergo luteinization and become secondary (accessory) corpora lutea. It is not certain whether these follicles undergo a “silent” ovulation or merely luteinize without releasing an egg in the process of luteinization. These additional CL result in a further increase of serum progesterone concentrations to maintain the pregnancy. As eCG ultimately increases progesterone concentrations, it is possibly required for boosting progesterone production by the ovary during the first half of pregnancy. It does not have the same early function as hCG in the human, which serves to rescue the CL of pregnancy around the time of implantation. Because endometrial cup cells are a hemi-allograft and genetically foreign to the mother, she eventually mounts an immune attack against them, which renders the endometrial cups non-functional at about day 120 of gestation. At this point, the placenta assumes the progesterone-producing role. Hippomanes, which represent free-floating allantoic calculi, are another peculiarity of the equine placenta. Furthermore, the equine placenta, unlike that of other species placenta that has loose areolar connective tissue, is comprised of dense irregular connective tissue.

Projecting into the allantoic fluid are peculiar invaginations of the allantochorion. They are first found at a fetal body length (FBL) of about 11 cm and occur in juxtaposition with the endometrial cups whose secretion accumulates in them. Their size corresponds with the secretory activity of the endometrial cups, being largest at FBL 15–20 cm, and regressing after FBL 30 cm. When distended with secretion they are appropriately called allantochorionic pouches. They are few in number, not more than six, and are sometimes absent. The endometrial cups are crateriform structures which are disposed in a concentric manner at the base of the pregnant horn. They are present from the sixth to the 20th week of gestation, and in them the equine chorionic gonadotrophin (eCG) is produced. The endometrial cups are formed from cells which invade the endometrium from the trophoblastic girdle of the embryo; this invasion provokes a reaction by the maternal tissue and leads to the dehiscence of the endometrial cups at about day 140. The immunological importance
of the endometrial cups in protecting the ‘foreign’ conceptus has been demonstrated. In interspecies transfers of fertilised eggs between horses and donkeys no endometrial cups were formed, and the donkey fetuses died at 80–90 days. The surface of the allantochorion adherent to the endometrium is red in color and has a ‘velvety’ appearance and texture. The area adjacent to the internal opening of the cervix is devoid of placental villi, giving rise to the so-called ‘star’. The inner surface of the allantochorion which is outermost when the placenta is shed has a smooth surface. In the early part of the second month of pregnancy, the endometrial cups are formed. These are discrete outgrowths of densely packed tissue within the gravid horn, derived as a result of the invasion of fetal trophoblast cells into endometrium, where they subsequently give rise to the endometrial cup cells. Usually, there are about 12 cups present at the junction of the gravid horn and body as a circumferential band.

The endometrial cups produce pregnant mare serum gonadotrophin (PMSG), which is now referred to as equine chorionic gonadotrophin or eCG. It is first demonstrable in the blood 38–42 days after ovulation, reaches a maximum at 50–65 days, declines thereafter and disappears by 150 days of gestation. eCG has both ‘follicle-stimulating hormone (FSH)-like’ and ‘luteinising hormone (LH)-like’ activity, and it is generally assumed that, in association with pituitary gonadotrophins, it provides the stimulus for the formation of accessory CLs and regulates luteal steroidogenesis. These structures start to form between 40 and 60 days of gestation, either as a result of ovulation, in the same way that the CL of dioestrus is formed (32%), or as a result of luteinisation of anovulatory follicles (68%). Because of the presence of the accessory CLs, the progesterone concentrations in the peripheral circulation increase, to reach and maintain a plateau from about 50 to 140 days and then decline. By 180–200 days the concentrations are below 1 ng/ml, and they remain so until about 300 days of gestation, when they increase rapidly to reach a peak just before foaling and subsequently decline rapidly to very low levels immediately after parturition. The endometrial cups regress spontaneously at 90–150 days. There is currently no practical way of destroying endometrial cups prematurely. If early fetal death occurs after endometrial cup formation at 36 days, mares will either become anoestrous or come into oestrus. However, in the latter, follicular luteinisation without ovulation is thought to occur and therefore the oestrus is not fertile; this will last until the endometrial cups regress spontaneously at 90–150 days. There is currently no practical way of destroying endometrial cups prematurely. A further complication is that if embryonic fetal death occurs after the formation of the endometrial cups, these latter structures persist until they spontaneously regress as if pregnancy had been maintained, resulting in pseudopregnancy.

The presence of follicle-stimulating hormone (FSH) in the blood of pregnant camels using immature female mice has been demonstrated, as in the method in the mare. The mouse ovaries showed marked follicular activity when injected with the blood of camels pregnant with fetuses of fetal body lengths between 11 and 58 cm. However, the authors did not mention any spate of follicular activity in the maternal camel ovaries, as occurs in the mare, when equine chorionic gonadotrophin (eCG) is present. The present author has seen no such activity in his study of the pregnant camel; nor has he found endometrial cups that are the source of eCG. The source of the gonadotrophic factor in the camel is therefore unknown but it is presumably of placental origin.

**Fetal development and other changes**

Fetal growth is exponential throughout gestation, the rate increasing as pregnancy progresses. The average length of gestation is regarded typically as 280–
285 days but is to some extent dependent on breed, particularly of the sire. For example, the effect of sire breeds on the gestation period of Friesian cows. The continental beef bulls tend to produce longer gestation periods than Friesian and Hereford bulls. Pregnancy appears to occur more commonly in the right uterine horn than in the left at a ratio of 60:40, with the corpus luteum typically being on the same side, reflecting the slightly more active right ovary as reported by several authors. Identical twins, derived from a single fertilized ova, or twins resulting from two ovulations on the same ovary are likely to begin development in the same uterine horn. The resulting overcrowding can increase the chance of loss, unless one of the calves can migrate to the contra lateral horn. The bovine embryo itself, although differentiating fast, elongates slowly as compared with the chorion, and at a month after mating it is only just over 1 cm long. The chorionic vesicle, which is at first string-like with a central distended sphere of amnion containing the embryo, is progressively filled by allantoic fluid to form an extensive allantochorionic sac; this first begins to distend the gravid cornu at about 35 days. At this time, the chorion already extends into the non-gravid horn; its length is about 40 cm and at its widest part in the dependent portion of the gravid horn it is 4–5 cm in diameter. The early development of the sheep is very similar to that of the cow, but the equine conceptus does not show the initial rapid elongation of the blastocyst-chorion. For example, at 35 days the equine chorion is oval rather than cylindrical and is more distended by the allantoic fluid. This causes an earlier, more discrete uterine enlargement than in the cow and this is helpful in early clinical pregnancy diagnosis.

The allantois, which is an outgrowth of the embryonic hindgut, spreads out into the chorionic vesicle; as a protruding sac, it makes contact outwardly with the chorion to form the vascular allantochorion, and inwardly fuses with the amnion, to give rise to the allanto-amnion. The allantochorion, which eventually surrounds the allanto-amnion, is separated from it by allantoic fluid. When the vascularisation of the chorion by the allantois is complete (at 40–60 days in the cow) the allantochorion is ready to participate in placental function. Prior to this time, the embryo has been nourished through its chorion and amnion by diffusion from the uterine milk. In the ruminant uterus, where the allantochorion contacts the uterine caruncles, finger-like processes or villi containing capillary tufts grow out from the allantochorion into the crypts of the maternal caruncles, which are also surrounded by capillary plexuses. Thus is formed the characteristic ruminant cotyledon, or placentome, through which nutrient and gaseous exchange between the mother and fetus takes place. On average, there are some 120 functioning cotyledons in the cow and about 80 in the sheep, arranged in four rows along each of the uterine horns. It will be recalled that the chorion, and following it the allantois, extend into the non-gravid horn, and thus it is normal in the ruminant for there to be numerous functioning cotyledons in the non-pregnant horn. The pregnant uterus of the mare, sow, bitch and cat shows no cotyledons, for in these species the villi are dispersed over the placental area. During early development of the ruminant embryo, there occurs an extensive fusion between the allanto-amnion and the allantochorion, thus largely obliterating the cavity of the allantois. As a result, where it lies over the amnion, the allantois is reduced to a narrow channel. Here its shape resembles the letter ‘T’ with the stem coming out of
the urachus, along the umbilical cord and then diverging as the two cross-pieces over the lateral face of the amnion. Consequently there is little allantoic fluid over the amniotic area; most of it lies in the extremities of the allantois, one of which lies in the non-gravid horn. A similar fusion takes place between the amnion and allantois of the pig. However, studies of bovine uteri in late gestation have shown that, with the increasing pressure of accumulating allantoic fluid, the allantochorion tends to become separated again from the allanto-amnion so that at term the allantois may almost surround the amnion. Thus the final arrangement of the two fetal sacs may closely resemble that of the horse, in which species the amnion, except for its attachment at the umbilicus, floats freely in the allantoic fluid throughout gestation.

In carnivora, as in the domestic herbivora, the allantois also grows out into the cylindrical chorion, but only the central part of it becomes vascularised and serves as a placenta. The amnion is surrounded by allantoic fluid, as in the horse. A 35-day beagle embryo is 35 mm in crown–rump length and increases by 6 mm per day between the 35th and 40th days.

Fetal membranes consist of:
- The **allantochorion** or **chorioallantoic membrane (CAM)**. The outer surface of this membrane (chorion) is covered with microvilli which are composed of capillaries, a little stromal tissue and an epithelium. This surface looks velvet-like and is red in colour. The inner surface is shiny and through it can be seen the larger veins and arteries which emanate from the umbilical vessels.
- The **amnion**, which is formed by fusion of the allantois and amnion proper (this membrane would more correctly be called the **allantoamnion**). It is an opaque white membrane containing many tortuous blood vessels (these become straighter as pregnancy progresses).
- The amnion and CAM are completely separate from each other, and are only attached indirectly via the umbilical cord.
- The umbilical cord traverses the allantoic cavity, and, at the level of the amnion, the two veins join to form one vessel in the amniotic cavity.
- The amniotic part of the cord also contains the urachus, a canal which conducts fetal urine from the bladder to the allantoic cavity.
- The amniotic cord and inner surface of the amnion are often covered with small rough plaques of cells which contain glycogen.
- Twisting of the umbilical cord and/or dilations of the urachus are often associated with abortion.
- The **hippomane** is a soft calculus of cellular and inorganic debris which forms in the allantoic cavity. Occasionally there are accessory small hippomanes either free in the fluid or attached to the CAM, particularly on the chorioallantoic pouches (wrongly called ‘false hippomanes’).
The corpus luteum that forms after ovulation is called the primary corpus luteum. Progesterone production from the primary CL starts to decline from day 25 onwards. Secretion of eCG from the endometrial cups is first detectable between days 35 to 42 after ovulation, reaching peak concentrations at approximately day 60. It is thought that eCG is responsible for maintaining progesterone production from the primary CL, but in addition it is responsible in part for the development of secondary, also called accessory or supplementary CLs. These structures are formed from either ovulation or luteinisation of follicles that are present in the ovaries at this time.

**Hormonal changes during pregnancy**

Ovarian follicle development continues during pregnancy as a result of low levels of gonadotrophin secretion. Both ovarian follicles and the embryoplacental unit produce oestrogens. Changing ratios of this oestrogen and progesterone can cause some cows to show oestrus during pregnancy but this is not usually accompanied by ovulation. In the pig, oestrone sulphate is produced from oestrogen of embryonic origin, which is then conjugated to sulphate in the endometrium. In the cow, plasma milk oestrone sulphate concentrations rise gradually during pregnancy and their measurement is a means of pregnancy diagnosis. Plasma and milk progesterone concentrations rise during the first few days of pregnancy in a similar manner to that occurring in the early luteal phase of the non-pregnant animal. Cows with lower progesterone levels as soon as day 5 after insemination are likely to have lower pregnancy rates. The increase in progesterone, through the mediation of progesterone receptors in the uterus, brings about alterations in the pattern of secretions into the uterus, thus preparing it to support the fertilized embryo. It is generally considered that high progesterone levels are required for the maintenance of pregnancy. For this reason, the release of PGF2α into the uterine veins, normally associated with luteolysis, is abolished in the pregnant animal. This is mediated by the conceptus itself, which, by day 16, has produced from its trophectoderm sufficient quantities of the protein interferon tau (IFNt) to prevent the increase in oxytocin receptors that would otherwise be stimulated by estradiol from ovarian follicles. Oxytocin from the corpus luteum thus fails to initiate the final stage of PGF2α production and so, instead of declining from about day 17 or so, high progesterone concentrations are maintained, reflecting maintenance of the corpus luteum, for the duration of pregnancy. In some species, e.g. the pig and goat, the corpus luteum is required to maintain pregnancy throughout the gestation period. However, in the cow, although the presence of the corpus luteum is necessary up to day 200 and the corpus luteum secretes progesterone throughout pregnancy, if cows are ovariectomized after 200 days, normal pregnancy will nevertheless be maintained. There is evidence that in the pregnant cow a major source of progesterone during pregnancy is the adrenal glands. In many species including the cow the placenta is also a source of progesterone during pregnancy. Mean plasma LH concentrations are low during pregnancy. This low rate of LH release must be sufficient to maintain progesterone production at least during early pregnancy, unless other luteotrophic substances are involved. There is little information on the release of FSH during pregnancy, but it is logical to assume that it is secreted at relatively low levels. The placenta secretes a protein hormone, placental lactogen, which also has gonadotrophic properties.
PREVENTION AND TERMINATION OF PREGNANCY:

In all domestic species there will be occasions when it will be desirable to either prevent pregnancy occurring or terminate it prematurely. Such occasions may follow an unintended mating (misalliance), where pregnancy and parturition may present a severe risk to the dam’s health, or where the owners of the animal do not want the pregnancy to continue.

**Mare:**

If the pregnancy needs to be curtailed for this and other reasons, such as mismating, the treatment of choice is PGF2α or an analogue administered after the CL has become responsive to the hormone, i.e. 4 days after ovulation and before the formation of the endometrial cups, i.e. about 35 days. Therefore, it is preferable to treat approximately 10–15 days after mating. Alternatively, intrauterine infusion of 250–500 ml of physiological saline during the same period will also be effective, since as well as a physical effect in flushing out the conceptus, it also stimulates the release of endogenous PGF2α.

**Cow:**

Pregnancy can be terminated from 4–5 to 100 days after ovulation with PGF2α or an analogue, and even up to 150 days many cows will respond. After 150 days, the placenta is the major source of progesterone for the maintenance of pregnancy, until about 270 days of gestation; PGF2α alone is not effective. During this period, either long acting corticosteroids alone, or in combination with PGF2α are required. Large doses of estradiol benzoate can terminate pregnancy up to about 150

<table>
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<tr>
<th>Animal</th>
<th>Litter size</th>
<th>Period of gestation (in days)</th>
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<tbody>
<tr>
<td>Mouse</td>
<td>Multiple</td>
<td>19-21</td>
</tr>
<tr>
<td>Rat</td>
<td>6-9</td>
<td>22</td>
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<tr>
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<td>Guinea pig</td>
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<td>61-64</td>
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<tr>
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<tr>
<td>Elephant</td>
<td>1, occasionally 2</td>
<td>641-675</td>
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</table>
days by stimulating endogenous PGF2α release; however, it is not as effective as using the hormone directly.

**Doe goat:**
Pregnancy can be terminated at any stage with PGF2α.

**Ewe:**
PGF2α is effective in terminating pregnancy after day 4 and before day 12. During the day's 12–21 periods, there will be no response because of the protective effect of oIFN-τ which ensures the survival of the CL. There is also some suggestion of another refractory period between days 25 and 40. After 45–55 days, the CL is no longer the main source of progesterone for the maintenance of pregnancy, and at this stage corticosteroids will be necessary to terminate pregnancy.

**Sow:**
Pregnancy can be terminated at any stage with PGF2α.

**Bitch:**
Pregnancy can be prevented in the bitch by the strategic use of oestrogens during the first 5 days after mating. They exert their effects by interfering with the transport of the zygotes from the uterine tube to the uterine horns, probably by causing oedema of the endosalpinx and thus a temporary tubal occlusion. For many years, estradiol benzoate was used as a single intramuscular or subcutaneous injection at a dose rate of 5–10 mg. Signs of oestrus are prolonged, and it is not advisable to repeat treatment if a mating occurs again, since there is evidence that it predisposes to cystic endometrial hyperplasia (pyometra) if the treatment is repeated. Oral diethylstilboestrol and ethinyl estradiol treatment has also been used. More recently the use of lower doses of estradiol benzoate 0.01 mg/kg administered on the third, fifth and possibly seventh days after mating has been advocated since it is possibly a safer option. Attention has also focused on the termination of pregnancy at a later stage. Natural PGF2α rather than analogues has been found to be effective when administered at a dose rate of 150–270 μg/kg subcutaneously twice daily consecutively on days 10–14 after the bitch has entered metoestrus or pregnancy, as confirmed by exfoliative vaginal cytology. Earlier reports, in which pregnancy was terminated at a later stage, namely 25–30 days, resulted in unacceptable side-effects. At present, it is doubtful if PGF2α should be used for this purpose.

Recently a dopamine agonist, cabergoline, which also inhibits prolactin secretion and hence indirectly withdraws the luteotrophic support for the CLs, has been used to terminate pregnancy in bitches. It has been used at a dose rate of 1.65 μg/kg subcutaneously for 5 days at 25–40 days of gestation. Unlike the prolactin inhibitor bromocriptine, it does not have unpleasant side-effects, but since a resultant uterine inertia may result in retention of puppies which become macerated, it is not without dangers. Most commonly, carbergoline is administered orally daily (5 μg/kg), whilst cloprostenol (5 μg/kg) is given parenterally on alternate days. Abortion/resorption usually follows 10 days after treatment; however, termination of an unwanted pregnancy in the bitch should be closely monitored, particularly with sequential transabdominal B-mode ultrasound.

**Cat:**
Estradiol cypionate by intramuscular injection at a dose rate of 125–250 μg within 40 hours of mating has been shown to be effective in preventing pregnancy, probably by interfering with the normal transport of the zygotes within the uterine tubes. Similarly, injections of diethylstilboestrol have been used. However, there are little data on possible side-effects, and such treatments should only be used in exceptional circumstances. A single 5 mg dose of megestral acetate is used by some
within 1 day of mating. Recently, both PGF2α and the dopamine agonist cabergoline have been shown to be fairly effective in causing abortion; however, the former has unpleasant side-effects. Regimens using carbergoline and lowdose cloprostenol appear to be most promising.

**FETAL MOBILITY DURING PREGNANCY**

Fetal movement around both longitudinal and transverse axes is possible. Rotation about the first is limited by the length of amniotic umbilical cord and about the second when the length of the fetus exceeds the width of the amnion. In cattle, not more than a three-fourths revolution around the long axis is possible and, although several turns around the transverse axis may occur, a complete revolution of the bovine umbilical cord is not normal and has been seen only in mummified fetuses. In equine and porcine fetuses, however, complete revolutions of the amniotic portion of the umbilical cord are common. Another possibility of intrauterine fetal movement is the potential mobility of the amniotic sac (with contained fetus) within the allantochorion. Owing to the extensive fusion of the allantochorion to the allanto-amnion in the cow, ewe and sow, such mobility is impossible (except perhaps near term) whereas in the mare, bitch and cat such movement does take place and leads to twisting of the allantoic portion of the umbilical cord.

**Placental Hormones and Proteins:**

The placentas of all various species produce a wide array of hormones and other factors, whose main function is to aid in the survival of the conceptus during pregnancy and after birth (mammary development). Some of these hormones may achieve this goal by signaling to the mother that she is pregnant and preventing a new ovarian cycle from initiating. These hormones or factors are often said to be required for maternal recognition of pregnancy, others aid in nutrient acquisition or prolongation of the corpus luteum, which elaborates progesterone. In many species, the placenta itself may produce progesterone and other steroid hormones that suppress another estrous cycle.

**Human Chorionic Gonadotropin:**

The placentae of humans and non-human primates produce a chorionic gonadotropin (CG), which has a wide-range of effects. The best characterized of these is the ability of CG to extend the CL lifespan, i.e. luteotropic effect. In response to CG, the CL continues to elaborate progesterone and relaxin. CG is thus considered to be the maternal recognition of pregnancy signal in primates. CG may also promote a favorable uterine environment for the conceptus by facilitating blastocyst implantation into the endometrium, inducing vasodilation of myometrial blood vessels, and myometrial smooth muscle relaxation. CG may stimulate progesterone synthesis in the conceptus. Human CG may be detected seven to eight days after gestation in maternal serum and a few days later in the urine. CG is composed of a non-covalently bound α- and β-subunit with the β-subunit conferring specificity of this hormone. Peak level of hCG is detected in the maternal serum at seven to nine weeks gestation, whereupon this hormone begins to decline. Interestingly, in late pregnancy, female conceptuses produce higher concentrations of hCG than males. CG has been clinically useful in pregnancy diagnosis and monitoring and prenatal screening, and the purified or recombinant form of CG can be used to induce ovulation as part of a superovulatory regimen in humans and several other species, including domestic animals.

**Interferon-τ (IFN-τ):**

IFN-τ is produced exclusively by the ruminant placenta and is the maternal recognition of pregnancy signal in these species. IFN-τ is produced by small and large
ruminant placentae between days 10 and 25 of gestation with peak activity on days 14 to 16. The net effect of IFN-τ is to prolong the CL lifespan by suppressing the production of the luteolytic factor PGF2α by the endometrium. It is believe that IFN-τ abates the luteolytic cascade by entailing inhibition of uterine estrogen receptor expression, which in turn causes the loss of uterine oxytocin receptor from the uterine cells. Binding of oxytocin to its uterine cognate receptor induces the release of PGF2α by the endometrium. In the absence of uterine oxytocin receptor (OTR), oxytocin is incapable of stimulating the release of PGF2α. Similar to hCG, bovine female conceptuses initially produce higher concentrations of IFN-τ than their male counterparts.

**Pregnancy-associated Glycoproteins:**

Pregnancy-associated glycoproteins (PAG) are classified as inactive members of the aspartic proteinase family, and thus, these proteins are related to pepsin and chymosin as well as cathepsins. The ruminant placenta produces several isoforms of the PAG. The porcine, equine, and feline placentae express PAG or PAG-like molecules. While these ruminant proteins are produced in large amounts, particularly by ruminant placentae binucleate cells, their function is uncertain. Even though the function of these proteins remains elusive, PAG are clinically useful in pregnancy determination in cattle and small ruminants because these proteins can be detected in pregnant maternal plasma or serum.

**Placental Lactogens and Prolactin:**

The placentae of ruminant artiodactyls, rodents, and humans produce a variety of compounds that are related to pituitary prolactin and growth hormone. These placental compounds are classified as either placental lactogens (PL) or prolactin related proteins. Their precise functions are uncertain, but these molecules presumably regulate maternal and fetal metabolism and possibly increase insulin-like growth factor (IGF) in the conceptus, which may increase fetal growth. Ruminant PL has both lactogenic and somatogenic effects and therefore may stimulate mammogenesis in preparation for lactation. In late gestation, the concentration of PL increases in the maternal circulation but decreases in the fetal circulation, which further suggests a role for PL in the dam.

**Equine Chorionic Gonadotropin (Pregnant Mare Serum Gonadotropin):**

At days 35 to 37 of pregnancy, these fetal cells migrate from the chorionic girdle region and infiltrate into the underlying endometrium. These cells begin to produce eCG (or PMSG), which is similar to other gonadotropins and comprised of α- and β-subunits. Within each equid species, the α-subunit is identical among all of the gonadotropins. The β-subunit of eCG confers specificity of this hormone and is identical to its equine luteinizing hormone counterpart. Because eCG is produced after implantation has occurred, this hormone is not considered the equine maternal recognition of pregnancy signal. Instead, eCG stimulates additional follicular development culminating in accessory or secondary CL that helps to maintain the elevated progesterone concentrations during mid-gestation. Peak eCG secretion occurs during 60 to 80 days of gestation followed by a gradual decline until 130 days of gestation. At this time, the maternal immune system mounts an immune attack against the fetal endometrial cup cells, which produce eCG. After 130 days of gestation, the equine placenta, as discussed below, assumes the progesterone producing role.

**Steroid Hormones:**

In several domestic animal species, including ruminants, equids, and possibly swine, the placenta synthesizes progesterone during the latter half of gestation. The CL is the
primary structure responsible for elaborating progesterone. However, in late gestation, particularly in the horse and other species, the placenta assumes the role of producing progesterone that is necessary for the pregnancy to continue. In sheep, placental progesterone may suppress the uterine immune attack on the developing conceptus. Estrogen is another steroid hormone that is produced by the placentae of several domestic animals. In the pig, estrogen production by the conceptus is essential for maternal recognition of pregnancy. Estrogen from the porcine conceptus redirects endometrial PGF2 into the uterine lumen and consequently, away from the utero-ovarian vasculature and CL. By shifting PGF2 away from the CL, estrogen prevents luteolysis, and thus the CL is maintained.
MATERNAL RECOGNITION OF PREGNANCY

In most domestic species, the establishment and maintenance of pregnancy require that the luteal phase of the estrous cycle is prolonged by the persistence of a single corpus luteum (CL) or a number of corpora lutea (CLs). As a result of the persistence of the luteal tissue, progesterone concentrations remain elevated. This results in a negative feedback on the hypothalamus and anterior pituitary with a resultant inhibition of follicular development and ovulation and, in polyestrous species, a prevention of return to oestrus. In many species, the placenta subsequently replaces or supplements the luteal source of progesterone. The presence of a viable, developing embryo(s), however, prevents the CL from regressing and thus, in polyestrous species, inhibits the return to oestrus. This phenomenon was described by Short (1969) as the ‘maternal recognition of pregnancy’. It is particularly interesting because a maternal endocrine response is detectable before the blastocyst is attached to the endometrium by microvilli, which either directly or indirectly prevent regression of the CL. In five of the domestic species the time of maternal recognition of pregnancy has been determined.

During early pregnancy, the blastocyst must signal its presence to the maternal system to stimulate CL maintenance for establishment of pregnancy.

The term “Maternal Recognition of Pregnancy” (first coined by Short in 1969) is usually associated with prevention of CL regression when applied to domestic species. However, the definition is inappropriate for marsupials and other Eutherian species such as the dog and ferret.

Maternal Recognition of Pregnancy can be defined simply as a functional relationship between the uterus, CL and embryo itself.

In most eutherian mammals, maternal recognition of pregnancy is established when the length of the estrous cycle exceeds that of the normal cycle. The signal which originates from the pre-attached blastocyst acts either directly at the endometrial level (gilt, mare, cow, and ewe) or indirectly at the ovarian level (human) to block the action of prostaglandin F2a (PGF2a).
Function of the Corpus Luteum

Ludwig Frankel pioneered the role of the corpus luteum in pregnancy maintenance when he demonstrated that removal of the CL (ovariectomy) from a pregnant rabbit terminated pregnancy.

Gilt - Ovariectomy at any stage of gestation will terminate pregnancy. However, Dziuk demonstrated that if CL were removed slowly, one CL could support pregnancy.

Cow - Ovariectomy up to 210 days of gestation will terminate pregnancy. After 210 days no effect - adrenal and placenta are sources of progesterone.

Ewe - Ovariectomy up to 50 days of gestation will terminate pregnancy.

Mare - CL normally regress approximately Day 150 of gestation

Woman - No effect after Day 24.

Although the end result is the same, several different mechanisms for maternal recognition of pregnancy have evolved in different groups of mammals. Some of this diversity can be appreciated by looking at humans, cows and dogs:

Blastocysts of humans and other primates secrete large quantities of a protein hormone called chorionic gonadotrophin (CG), which is very similar to luteinizing hormone. CG binds to luteinizing hormone receptors in the corpus luteum and stimulates continued secretion of progesterone. It may also block signals in the corpus luteum that cause luteal regression.

In cattle and other ruminants, the corpus luteum regresses at the end of the non-pregnant cycle as a result of secretion by the endometrium of prostaglandin F2 alpha (PGF). The early ruminant embryo secretes copious quantities of a protein called interferon tau. Exposure of the endometrium to this hormone dampens the secretion of PGF, thereby blocking the signal for luteolysis. As a result, the corpus luteum survives and progesterone levels are maintained.

Dogs do not have multiple, sequential cycles like women or cows. Rather, they have a single cycle roughly every 4 to 6 months. Following ovulation, the pattern of progesterone secretion is essentially the same regardless of whether the bitch is pregnant or not. Consequently, dogs do not have a need for maternal recognition of pregnancy and apparently no mechanism for this process.

Several other interesting variations in maternal recognition of pregnancy have been characterized among mammals. The common theme is that the early conceptus is the source of the signal that interferes with normal luteal regression at the end of the cycle. This makes good biological sense - in essence, the embryo is shouting out its presence to the corpus luteum, saying please do not regress, I need your support!
TYPES OF PLACENTA

1-Placentae may be classified according to the way the villi are distributed on the fetal chorion. Thus, where they are uniformly dispersed, as in the mare and sow, the placenta is said to be diffuse. Where they are grouped into multiple circumscribed areas, as in the ruminant, the placental arrangement is called cotyledonary, while in the bitch and cat the villi are disposed in the form of a broad encircling belt forming a zonary placenta, discoid in man.

Classification Based on Placental Shape:

Diffuse Placenta: Examples of the diffuse placenta can be observed in the pig and horse (King, 1993b). In swine, the placenta is completely non-invasive. The chorionic villi are not localized to a particular region but are instead distributed nearly over the entire surface of the uterine lumenal epithelium. The closely packed and convoluted chorionic villi yield an extensive surface area to facilitate movement of diffusible molecules between the maternal and fetal circulations and participate in the uptake of nutritional secretions from uterine glands. The equine placenta, while still considered diffuse, is distinct from the sow placenta in that it possesses localized regions of contact known as microcotyledons and an invasive trophoblast population known as chorionic girdle cells that, upon migration into the uterine endometrium, can form transitory structures known as endometrial cups.

Cotyledonary Placenta: Ruminant ungulates possess a cotyledonary placenta. The cotyledons are vascularized villous trophoblasts that intercalate into aglandular structures in the uterine endometrium known as caruncles. The fetal cotyledons begin to associate with maternal caruncles early in gestation and interdigitation of these tissues is well underway by day 35 in ewes and day 45 in cattle. Together, the combined unit of cotyledons and caruncles is referred to as a placentome.

Zonary Placenta: Numerous species, including carnivores, possess a zonary placenta. This type consists of a band of chorion surrounding the middle of the fetus. This zone of chorion forming the most intimate contact with the maternal uterus is the basis for the name of this placenta type.

Discoid Placenta: Higher primates and rodents possess a placenta that is characterized by one or more distinct discs comprised of localized regions of fetal chorion that interface with uterine tissues, thus the descriptive name “discoid”.

2-Formerly, the placentae were differentiated according to whether or not maternal tissue separated off with the fetal tissue at birth. Thus, of the domestic mammals, non-deciduate the placentae of the ma, bitch and cat were said to be deciduate.
According to histology, **epitheliochorial** type of placenta, seen in the horse and pig, the chorion is everywhere in contact with the endometrium, and there is no loss of maternal tissue. In the cow, the placenta is described as being **synepithelialchorial** in the third, **endotheliochorial** type, there which is now apposed to the maternal capillaries. Such a type is typical of the carnivora. In the **haemochorial** placenta of primates (man) only the tissues of the chorionic villi separate the fetal and maternal blood. The placenta of the dog and cat is partly haemochorial in that the main zonary placenta of endotheliochorial type is flanked by marginal haematomata – ‘the green border’ in the dog and ‘brown border’ in the cat – in which an accumulation of maternal blood between the uterine epithelium and the chorion directly bathes the chorionic villi that project into it.

**Epitheliochorial**

In this form of placentation, all three maternal layers are intact, which results in the complete six layers (maternal endothelium, maternal connective tissue, maternal epithelium, fetal epithelium, fetal connective tissue, and fetal endothelium) separating maternal blood from fetal blood. The main species in which this form of placentation is present include the mare, sow, and some ruminants.

**Synepithelialchorial (Syndesmochorial):**

In several ruminant species, e.g. cattle and sheep, some chorionic epithelial cells are binucleated and migrate and fuse with the maternal epithelium. Multinucleated giant cells present on the fetal side are termed trophoblastic giant cells, and those on the maternal side are cryptal giant cells. As discussed below, these multinucleated cells produce various hormones and proteins. This fusion of maternal and fetal epithelial cells results in areas where the chorion directly contacts the lamina propria of the endometrium. These regions have five layers (maternal endothelium, maternal connective tissue, fetal epithelium, fetal connective tissue, and fetal endothelium) separating maternal from fetal blood.

**Endotheliochorial**

This type of placentation is characterized by the loss of uterine epithelial lining and underlying connective tissue layer, which results in the chorion contacting the endothelium of the maternal capillaries. Only four layers (maternal endothelium, fetal...
epithelium, fetal connective tissue, and fetal endothelium) separate maternal blood from fetal blood in this case. Carnivores, felines, and canines are the classic species example for endothelialchorial placentation.

**Haemochorial**

In this case, maternal blood directly bathes the trophoblast cells. With only three layers separating maternal blood from fetal blood, nutrient and gas exchange readily occurs in these species. Primates and rodents are the main species that have this form of placentation. Interestingly, armadillo and bats also have the haemochorial form of placentation.

**FETAL FLUIDS**

The total volume of fetal fluid in ewes increases with advancing age of the conceptus, but that the separate fetal fluid volumes show different tendencies. Thus, during the first 3 months, apart from an initial preponderance, the allantoic fluid accumulates slowly, e.g., 131 ml at 3 months, whereas the increase in amniotic fluid occurs largely during this time and at 3 months reaches 604 ml. In the fourth month the increase in allantoic fluid is greatly accelerated to 485 ml, while the amniotic fluid increases only slightly. During the last (fifth) month of gestation the allantoic fluid almost doubles its volume to 834 ml but the volume of amniotic fluid diminishes to 369 ml. When twins are present, the totals of fluid are approximately doubled.

The total quantity of fetal fluid of cattle increases progressively throughout pregnancy; it averages about 5 litres at 5 months and 20 litres at term. Sharp rises in the total quantity occur between 40 and 65 days, between 3 and 4 months and again between 6 1–2 and 71–2 months. The first and last of these are due to allantoic and the second to amniotic increases. For nearly the whole of the first third of pregnancy, when the conceptus consists of an elongated allantochorion with a central spheroidal amnion — closely investing the relatively small embryo — there is more allantoic fluid; during most of the second third of pregnancy amniotic fluid predominates but for the greater part of the final third allantoic fluid is again clearly in excess. Throughout gestation the allantoic fluid is watery or urine-like. In the first two-thirds of pregnancy the amniotic fluid is similar, but for the remainder of gestation it is a mucoid fluid. The latter change gives it the lubricant property which is so helpful at parturition. At birth the allantoic sac forms the first and the amnion the second ‘water-bag’. The allantochorion is thicker and tougher than the transparent amnion. The amniotic fluid in the mare volume differs from that of cattle. It is low during the first 3 months: for example, only 27 ml at 74 days. Thereafter it increases more rapidly and at mid-pregnancy equals the volume of allantoic fluid, while at term it is 3–5 litres.

**Position of uterus during the pregnancy period**
During the early stages, detection of an increase in size of the uterus affords strong evidence of pregnancy, but the recognition of these changes necessitates an appreciation of the size of the quiescent uterus in subjects of varying ages and parity, the quantities of fluid present in the respective fetal sacs and the disposition of those sacs in the uterus. At 28 days of pregnancy the amniotic sac is spherical in outline and about 2 cm in diameter. It occupies the free portion of the gravid horn. The allantoic sac is about 18 cm long, but the amount of contained fluid is insufficient to distend it, and its width is negligible. It occupies almost the whole of the gravid cornu. At this stage the embryo is 0.8 cm long, a quite inappreciable size. At 35 days, fetal body length is 1.8 cm and the diameter of the spherical amniotic sac 3 cm. They still occupy the free part of the cornua. The conjoined portions of the cornua and the free portion of the non-gravid cornua are not appreciably changed. It is possible, particularly in a heifer easy of examination, that the distension in the free part of the gravid cornua will be detected. At 60 days the fetal crown–rump length is approximately 6 cm. The amniotic sac is oval and tense, having a transverse measurement of about 5 cm. This causes the free part of the gravid horn to be distended to a width of about 6.5 cm, compared with 2–3 cm in the quiescent stage in the heifer and young cow. In such subjects this distension may be recognized. At 80 days the fetus measures 12 cm and the total quantity of fluid is about 1 liter. Distension of the free part of the gravid horn varies from 7 to 10 cm, while that of the conjoined part is but little greater than normal. The greater length of the gravid horn can often be detected. By 90 days, uterine distension is such that it can be detected with accuracy in the great majority of cases. The conjoined cornua are tense, the gravid one having a width of about 9 cm and the non-gravid one about 4.5 cm. In most individuals the organ is still high up at the pelvic brim and it is generally possible to pass the hand well over the curvature of the distended horn, but in some multigravid cows the uterus lies in the abdomen, and to palpate it effectively it is necessary to retract the organ. Sometimes it is possible to detect the fetus at this stage. Tapping of the distended cornua with the fingers may reveal the fetus rather like a piece of wood floating in the fluid beneath. By gently squeezing the uterus one may be able to pick up the fetus. Its body length is about 15 cm. By the fourth month the uterus sinks below the pelvic brim, and distension is less easy to recognize as the fluid gravitates towards the extremities of the cornua. The cervix lies on the pelvic brim. During the period 120–160 days, it will be possible to palpate the fetus in more than 50% of cases. The presented extremity will lie within reach in front of, and below, the pelvic brim. In some cases, the fetus may be touched transiently at the commencement of examination and then sinks into the depths of the uterus beyond reach. Similarly, if a series of examinations of an individual is made during this period, the fetus may be detected on some occasions and not others. Between 5.5 and 7.5 months the fetus is detected less often than during the previous period. The author would put it at 40–50%. In favorable cases the fetal head and/or flexed limbs are palpated just anterior to the pelvic brim. Touching the fetus often provokes reflex movement. From 7.5 months to the end of gestation the fetus will, in the majority of cases, be detected readily. Again, however, cases will be encountered, especially in deep-bellied, multiparous cows in which the fetus cannot be detected, at any rate on a single examination, even to term. Several authors have shown variations in myometrial tone during late pregnancy. They found that in a large number of Hereford heifers, which were examined daily by rectal palpation near term, it was frequently impossible to palpate the fetal calf. The reason for this finding was the considerable relaxation of the myometrium, which allowed the calf to descend into the abdomen.
Non-gravid cornu:

The extent to which the allantochorionic sac occupies the non-gravid horn varies greatly. In the great majority of bovine pregnancies the sac occupies some part of it, in some extending to the apex. In others, the caudal two thirds or one-half only is occupied, while in exceptional cases the non-gravid horn is entirely unoccupied by fetal membranes. In the majority of cases, the non-gravid horn also plays its part in placentation and its cotyledons hypertrophy, although the degree of cotyledonary enlargement is not as great as that of the pregnant horn. Occasionally the non-gravid horn, although occupied by the allantochorion, plays no part in placentation and its cotyledons remain undeveloped. In such cases, and also in those in which the non-gravid horn is unoccupied, the cotyledons in the gravid horn, particularly those in the region of the fetal trunk, become grossly hypertrophied and may at the time of parturition be as large as 8 x 12 cm. Detection of the hypertrophied cotyledons is evidence of pregnancy, but variations occur in their size at the various stages of pregnancy in different individuals. This is probably due to differences in number. Again there is variation throughout the same uterus. Those situated about the middle of the gravid cornu are larger than those of the extremities, while those in the non-gravid horn are smaller than those in the gravid one. (Occasionally there is no placentation in the non-gravid horn.) As pregnancy continues, they become progressively larger, until in the terminal stages they may be 5–6 cm in diameter, but because the pregnant uterus sinks into the abdomen, it may not be possible to palpate cotyledons from the fifth to the seventh month. It is generally accepted that dairy cows are more often pregnant in the right horn, and that the CL is in the ovary on the side of the pregnant horn. In a large series of pregnant bovine uteri examined the proportion has been 60% right-side pregnancies to 40% left-side; in only one case was the fetus present in the horn opposite to the ovary containing the CL; another case showed a CL of normal size in each ovary with a single fetus in the right horn. There is an incidence of 1.04% of twins in dairy cattle and 0.5% in beef cattle. Individual breed records show higher figures: 2.7–8.85% for Brown Swiss, 3.08–3.3% for Holsteins, 2.8% for Ayrshires, 1.95% for Guernseys and 13% for Jerseys.
Figure 7.2  (a) Diagram of an equine conceptus at 30 days: the developing allantois is pushing the embryo dorsally and the vascular mesoderm is enveloping the yolk sac. (b) Diagram of part of the equine conceptus at 55 days: the yolk sac is becoming vestigial and will be enveloped by the blood vessels of the umbilical cord.
PREGNANCY AND ITS DETECTION IN THE MARE:

The endocrine changes in the mare during pregnancy are particularly unusual, when compared with other domestic species, because of the development of temporary hormone-producing structures, the endometrial cups.

After ovulation and the formation of the corpus haemorrhagicum and the CL, plasma progesterone concentrations in the peripheral plasma rise to 7–8 ng/ml by 6 days. They persist at about these levels for the first 4 weeks of gestation, but there is frequently a transient fall at about 28 days after ovulation to 5 ng/ml, followed by a later rise. Published values for progesterone in the blood and plasma vary considerably between laboratories. This is because there are other progesterone-like substances which cross-react with the antisera during the assays, for this reason several authors refer to ‘total progestogen’ levels. In the early part of the second month of pregnancy, the endometrial cups are formed. These are discrete outgrowths of densely packed tissue within the gravid horn, derived as a result of the invasion of fetal trophoblast cells into endometrium, where they subsequently give rise to the endometrial cup cells. Usually, there are about 12 cups present at the junction of the gravid horn and body as a circumferential band. The endometrial cups produce pregnant mare serum gonadotrophin (PMSG), which is now referred to as equine chorionic gonadotrophin or eCG. It is first demonstrable in the blood 38–42 days after ovulation, reaches a maximum at 60–65 days, declines thereafter and disappears by 150 days of gestation. eCG has both ‘follicle-stimulating hormone (FSH)-like’ and ‘luteinising hormone (LH)-like’ activity, and it is generally assumed that, in association with pituitary gonadotrophins, it provides the stimulus for the formation of accessory CLs and regulates luteal steroidogenesis. These structures start to form between 40 and 60 days of gestation, either as a result of ovulation, in the same way that the CL of dioestrus is formed (32%), or as a result of luteinisation of anovulatory follicles (68%). Because of the presence of the accessory CLs, the progestogen concentrations in the peripheral circulation increase, to reach and maintain a plateau from about 50 to 140 days and then decline. By 180–200 days the concentrations are below 1 ng/ml, and they remain so until about 300 days of gestation, when they increase rapidly to reach a peak just before foaling and subsequently decline rapidly to very low levels immediately after parturition. The main source of progesterone in early pregnancy is the true corpus luteum and the accessory corpora lutea. The true corpus luteum is active for the first 3 months of gestation, and regresses at the same time as the accessory corpora lutea. The placenta must take over the production of progesterone after the regression of the accessory corpora lutea, and although concentrations fall in the peripheral circulation they remain high in the placental tissue and must maintain pregnancy by virtue of a localised effect. When ovariectomy is performed at 25–45 days of gestation, mares will abort or resorb the fetus; when it is performed after 50 days the response is variable; between 140 and 210 days the pregnancy is continued uninterrupted to term. Thus after 50 days there is evidence of
a non-ovarian source of progesterone, and by 140 days the ovaries are no longer necessary for the maintenance of pregnancy.

**Changes in the genital organs:**

The corpus luteum verum can only be palpated per rectum for 2 to 3 days after its formation. Thereafter, although it persists for 5 or 6 months, it cannot be identified. During late dioestrus and oestrus, the uterus is soft and the endometrium is edematous. After ovulation, tone increases and the uterus becomes more tubular; these textural changes are not marked in the non-pregnant animal, in which they subside after the CL begins to regress at 10–14 days, but in the pregnant mare the CL persists, and the tone of the uterus increases to a maximum at 19–21 days, when the conceptus causes a soft, thin-walled ventral cornual swelling close to the uterine body. The horn involved is not necessarily on the same side as the ovary which produced the ovum, because there is extensive mobility of the conceptus within the horns and uterine body before fixation occurs between days 16 and 18.

**Methods of pregnancy diagnosis:**

**Basic examination of the reproductive tract consists of:**
- Visual examination of the tail, perineum and vulva;
- Manual palpation of the cervix, uterus and ovaries per rectum;
- Visual inspection of the vagina and cervix per vaginam using a speculum;
- Manual palpation of the vagina and cervix per vaginam;
- Real time ultrasound imaging per rectum.
- Endoscopic examination of the vagina, cervix and uterus in some cases.

**Restraint of the mare:**

**Stocks**

Stocks are probably the best method of restraint but:
- The mare may not enter easily, especially for first time;
- Mares may try to jump out, especially to join a companion or foal (it may be possible to put the foal in the stocks with the mare, otherwise the foal is best placed directly in front of the stocks);
- Ensure that the back panel of the stocks is low;
- Stocks should be readily dismantlable as occasionally mares become cast.

**Twitch**

A twitch is a very useful method of restraint and may be the only form necessary for most mares, but:
- Some owners resent the application of a twitch to their mare;
- Some mares are very difficult to twitch;
- Some mares won’t move when twitched, so position them correctly beforehand;
- Some mares try to go down when twitched tightly;
- Twitching will not always control a willful mare;
- Humane twitch is easy to apply and leaves no mark on the nose.

**Bridle**

May be used with twitch or other methods. Helps the handler to stop the mare moving forward; a chiffney bit gives best control.

**Bales**

Bales of hay or straw behind the mare give some degree of protection against kicks, but:
- Mare may resent presence of bales;
- Mare may take a step forward during initial examination;
• Width of the bale makes examination of large mares difficult.

Other methods of restraint
Lifting a front leg, on the side of the examiner, stops the mare from kicking with the ipsilateral back leg, but:
• The clinician may have to stand directly behind the mare;
• The back end of the mare tends to be lowered, which makes rectal examination particularly difficult;
• An inexperienced helper may suddenly release the forelimb, or take too much of the mare’s weight so that she can still kick. Turning the mare’s head towards the examiner helps to prevent her kicking with the hind leg on that same side. Hind-leg hobbles help to prevent kicking but are seldom used in the UK. Low doses of the a2-adrenoceptor agonists (detomidine, romifidine, xylazine) may be useful; especially since they are anxiolytic.

Approach of the clinician:
Avoid sudden movements and loud noises, but try to converse with helper in an even voice, or hum or whistle.

When mare is not in stocks, approach her from the side, put one hand on the back, run it to base of the tail, grasp tail and pull it to one side.
• At this stage, mare’s temperament and effectiveness of restraint will become apparent.
• Feel for discharge (wet or dried) on tail, and inspect perineum.
• For manual examination per rectum or per vaginam, the arm can be inserted initially without the operator standing directly behind the mare. As examination proceeds, more of the clinician’s body is behind the mare, but at this stage her likely reaction has been anticipated.
• For speculum examination per vaginam, it is most convenient for an assistant to hold the tail (in a gloved hand) to allow the clinician a free hand to part the vulval lips.

External examination:
• Normal vulva – nearly vertical in position, no distortions (scarring) or discharges;
• Sunken anus (due to old age, poor condition) – common in Thoroughbreds and causes cranio-dorsal displacement of dorsal commisure of the vulva. This encourages contamination of the vulva and vestibule by faeces, and predisposes to pneumovagina.
• Mare with flat-crouped conformation – these mares often has a sunken anus and a resultant angulation of the vulva;
• Vulva already sutured (Caslick’s operation) to prevent pneumovagina;
• Lateral or dorsal tears to vulva;
• Small vesicles or ulcerated areas due to coital exanthema (herpes virus). Not to be confused with small depigmented areas, which are common?
• Vulval discharge. Varies from sticky moistness at ventral commisure to frank discharge (wet or dried) on thighs and tail. A small amount of moisture is normal during oestrus, especially after covering, when a temporary purulent discharge may be seen;
• Yellow urine stain (usually dry) on ventral commissure of vulva. Usually denotes oestrus (but not always present) – due to increased urinary frequency when showing (winking).

**Manual examination per rectum:**
• Due to the lateral position of the ovaries, one-handed rectal examination makes accurate palpation of the right ovary for the right-handed examiner (and vice versa) difficult if the mare is not well restrained.
• Wear a glove and use adequate lubricant.
• Mare usually resents passage of hand most and then the elbow.
• Completely evacuate rectum of faeces, and feel for uterine horns lying transversely in front of the pubis. Follow these laterally to the ovaries which are cranial to the shaft of the ileum.
• Always try to have the hand cranial to the structure which is to be palpated to allow sufficient rectum for manipulation.
• Do not stretch rectum laterally if tense; do not resist strong peristaltic contractions – otherwise rectum may tear (especially dorsally, i.e. not adjacent to examiner’s hand).
• If the rectum is ballooned with air, feel forward for peristaltic constriction and gently stroke with a finger to stimulate contraction.
• Ovaries often lie lateral to broad ligament and are difficult to palpate. They must be manipulated onto the cranio-medial aspect of the ligament for accurate palpation.
• Uterus is very difficult to palpate in anoestrus, easier during cycles and easiest during early (up to 60 days) pregnancy, due to increasing thickness and tone of the uterine wall.
• Cervix is palpated by sweeping fingertips ventrally from side to side in mid-pelvic area. It is easiest to feel during the luteal phases, but more difficult during oestrus and anoestrus.

**Visual examination per vaginam:**
• Requires optimal restraint, as operator will have to stand behind the mare.
• Clean perineum and vulva with clean water or weak disinfectant.
• Moisten or lubricate speculum.
• After introducing speculum through vulval lips, push cranio-dorsally to clear brim of pubis.
• At this point there is often considerable resistance at the vestibulo-vaginal junction (occasionally the speculum tries to enter the urethra).
• When fully inserted (30 cm), view vaginal walls and cervix.
• Make evaluation quickly, because artifactual reddening can occur following contact of speculum or air with vaginal wall.
• Evaluate shape, size, position, patency and color of cervix and vaginal wall.

**Types of speculum:**
1-**Metal.**
2-**Plastic.**
3-**Cardboard.** Tubular with silvered interior to reflect light. Requires separate light source. Slightly longer than plastic speculum but disposable and cheap – avoids resterilisation.

**Manual examination per vaginam:**
• May feel remnants of hymen – occasionally complete.
• Vagina dry in luteal phase and anoestrus, moist in oestrus, sticky mucus in pregnancy.
• Palpate cervix for shape, size and patency of canal.
• May detect adhesions or fibrosis in the cervix.
• Do not force finger along cervical canal if there is a possibility of pregnancy.
• Mare’s cervix will allow gentle dilation, without causing damage, at all stages of the reproductive cycle.
• Manual examination may not be possible if mare’s vulva is sutured excessively tightly.

**Methods of Pregnancy Diagnosis:**

1. **Absence of subsequent oestrus;**
   This method is commonly used by stud personnel and owners as an initial screening method. However:
   • Some mares show estrous behaviour when pregnant, and these mares may be mated, especially if restrained; this may cause embryonic death, if the cervix is opened during coitus – more likely in old or recently-foaled mares.
   • It is commonly assumed that the mare will be in oestrus 21 days after mating, and this is not necessarily true. Teasing may therefore be too late in either normal or short cycles.
   • If the mare returns home after mating the owners may not be able to recognize oestrus. This is especially true when there is no stallion or other appropriate stimulus.
   • Some mares which return to oestrus after mating may show no signs, especially those with foals (silent oestrus).
   • Non-pregnant mares may not return to heat, usually due to prolonged dioestrus (4.11) and occasionally due to anoestrus (at the end of the season or during periods of inclement weather).
   • Non-pregnant mares may enter lactational anoestrus, especially if foaling in January–March.
   • Non-pregnant mares may not demonstrate estrous behaviour if they are protective of their foal.

2. **Clinical examination;**
   • Ovarian palpation contributes little to pregnancy diagnosis as large follicles may be (and often are) present and the CL is not palpable.
   • Uterine and cervical changes.
     - At 18–21 days: good uterine tone and a tightly-closed cervix (as assessed per rectum or vaginam) are indicators of pregnancy.
     - 21–60 days: good uterine tone, swelling at the base of one or both (twins) uterine horns and tightly-closed cervix; all must be present for positive diagnosis.
     - 60–120 days: swelling becomes less discrete, uterine horns become more difficult to palpate and uterine body becomes more fluid filled and prominent. The extension of the broad ligament between the uterine horn and the ovary (the mesosalpinx) is pulled into a tight band. This is often a difficult time for pregnancy diagnosis. Continuity with the cervix helps identification of the uterus. Fetus can sometimes be ballotted.
     - 120 days to term: cervix becomes softer, fetus becomes more obvious. Dorsal surface of uterine body always in reach. Fetus often felt moving after six months.
   • **Optimum time for rectal examination** depends on:
     _ Experience of the clinician – later examinations (40–60 days) are usually easiest;
     _ Time of year – the later the examination the more time is lost if the mare is not pregnant;
     _ Value of mare – early positive examinations should be repeated to detect pregnancy failure. Repeat examinations are recommended up to 40 days. After this time, pregnancy failure is rarely followed by a fertile oestrus.

3. **Progesterone concentrations;**
• Progesterone concentrations in plasma (or milk) can be measured by:
  _ Radio-immunoassay: sample must be sent (delivered) to laboratory and the result may take two or more days to obtain;
  _ Enzyme-linked immunosorbent assay (ELISA) tests: these can be conducted in a practice laboratory and the results are rapidly obtained (horse plasma can be harvested in 30 minutes without a centrifuge). The cost per sample is lowest when many samples are assayed in a batch (standards do not need repeating).
• At 18–20 days post-ovulation pregnant mares should have plasma progesterone concentration above 1ng/ml but:
  _ Not all mares with high progesterone are pregnant (cf. prolonged dioestrus, early fetal death and mares with short cycles);
  _ Mistiming of sampling (relative to previous ovulation) will give erroneous results;
  _ Occasionally pregnant mares have low progesterone concentrations for short periods of time;
  _ Thorough clinical examination gives cheaper and more complete and accurate information on the mare’s reproductive status.

4- **Equine chorionic gonadotrophin (eCG):**
Equine chorionic gonadotrophin (eCG, PMSG) appears in the blood in detectable concentrations at approximately 40 days after ovulation and usually persists until 80–120 days after ovulation. The hormone is produced by the endometrial cups. The amount of eCG produced varies greatly from mare to mare, and mares carrying multiple conceptuses do not necessarily produce more than those with singleton pregnancies.
• Errors in the test are due to:
  _ Sampling at the wrong time;
  _ Some mares producing little eCG after 80 days;
  _ Mares in which pregnancy fails after the endometrial cups form continuing to produce eCG (false positive);
  _ Possible loss of potency in samples not tested immediately.
• eCG can be detected by radio-immunoassay (commercial laboratories), haemagglutination-inhibition test (commercial laboratories and test kit for practitioners) and latex agglutination test (test kit for practitioners).

5- **Placental oestrogens:**
Placental oestrogens reach peak concentrations in plasma and urine at 150 days, and concentrations remain high until after 300 days. The amount of oestrogen produced is so great that false positives do not occur due to other conditions. False negative results are also very rare after 150 days. Oestrogens are tested for in the urine – free oestrogens produce a color reaction with sulphuric acid. The Cuboni test is the most accurate but involves an extraction procedure using benzene (carcinogen) and acid. The Lunaas test is simpler, uses acids but is sometimes difficult to interpret. Plasma assays for oestrone sulphate are now commercially available.

6- **Ultrasound examination:**
Ultrasonographic methods have become increasingly popular in recent years mainly because they are accurate and can provide an immediate determination of the animal’s status, thereby assisting the husbandry and management of livestock.

**Three types of ultrasound have been used for pregnancy diagnosis:**
1-The ultrasonic fetal pulse detector was the first type that was used. This is based upon the Doppler phenomenon, in which high-frequency (ultrasonic) sound waves emitted from a probe, placed on the exterior of an animal or in the
rectum, are reflected at an altered frequency when they strike a moving object or particles, e.g. the fetal heart or blood flowing in arteries. The reflected waves are received by the same probe; the differences in frequencies are converted into audible sounds and amplified.

2-The ultrasonic amplitude depth analyser (A mode) relies upon a transducer head that emits high-frequency sound waves and receives the reflected sound, which is shown as a one-dimensional display of echo amplitudes for various depths, usually on an oscilloscope but also on the newer light-emitting diodes. This has been used successfully in many species, notably the sow.

3-A more recent development is that of the B (brightness) mode, which has become a very versatile tool in studying reproductive events in many species, in particular the mare.

It is worthwhile outlining briefly the principles behind the technique. The probe, or transducer, as it should be called, is applied to the skin surface or inserted into the rectum. The transducer contains numbers of piezoelectric crystals which, when subjected to an electric current, expand or contract and produce high-frequency sound waves. When these sound waves are transmitted through tissues an proportion, depending upon the characteristics of the tissue, will be reflected back to the transducer, where the returning echoes will compress the same piezocrystals, resulting in the production of electric impulses which are displayed as a two-dimensional display of dots on a screen. The brightness of the dots will be proportional to the amplitude of the returning echoes and hence will provide an image ranging from black, through various shades of grey, to white. Liquids do not reflect ultrasound, and thus are depicted as black on the screen, i.e. non-echogenic, whereas solid tissues such as bone or cartilage reflect a high proportion of sound waves, i.e. they are echogenic and appear white on the screen. Since a tissue–gas interface can result in up to 99% of the sound waves being reflected, it is important that air should not be trapped between the transducer face and the tissues to be examined. For this reason, a coupling medium or gel (usually methyl cellulose) is applied to the transducer face before it is placed on the skin or rectal mucosa so that air is eliminated. It is also important to select an area that is relatively hairless, or alternatively it may be necessary to clip the hair. The technique is frequently referred to as real-time ultrasound or imaging. This just implies that there are live or moving displays in which the echoes are recorded continuously. The transducers may have the piezocrystals or elements arranged side by side in lines (hence they are referred to as linear array transducers); the field under examination and the two-dimensional image are in the shape of a rectangle. Sector transducers contain a single crystal which oscillates or rotates to produce a fan-shaped beam. They allow ready access to most of the thoracic and abdominal viscera, although very superficial structures may not be readily identified because of the shape of the beam. Sector scanners require less skin surface contact, which can reduce the time required to examine each animal; hence they are used for the trans abdominal approach, especially in sheep. Linear transducers are usually cheaper to buy and more robust, and they produce a rectangular image which is easier to interpret. The transducer should be small enough to be cupped in the hand, smooth in contour, waterproof and easy to clean. Each transducer produces ultrasonic waves at frequencies of between 1 and 10 MHz. The most commonly used frequencies are 3.5, 5 and, more recently, 7.5 MHz. The lower-frequency transducers give better tissue penetration but poorer resolution. Since using the transrectal approach the structures requiring imaging are within a few centimeters of the transducer head, high-frequency equipment is the most effective. Thus, in the
case of the mare, using a linear array transducer transrectally to diagnose pregnancy, it is possible to identify a 3–4 mm conceptual vesicle with a 5.0 MHz transducer, whereas a 3.5 MHz transducer will only identify a vesicle of 6–7 mm diameter.

**Ultrasound terminology:**
- Tissues that markedly reflect sound (such as gas, bone and metal) appear white on the ultrasound screen and are called *echogenic*.
- Tissues that transmit sound (such as fluid) appear black on the ultrasound screen and are called *anechogenic* (or *anechoic*).
- Tissues that allow some transmission and some reflection (such as most soft tissues) appear as varying shades of grey and are called *hypechogenic* or *hyperechogenic* depending upon their exact appearance.
- Strictly speaking, a hyperechogenic tissue produces a hyperechoic region within the image, although these terms are often used synonymously.

**Imaging technique:**
- The examination should be performed out of direct sunlight, since this can hinder interpretation of images on the ultrasound screen.
- The ultrasound transducer is usually held within the rectum in the sagittal (longitudinal) plane during imaging.
- The vestibule and vagina lie within the pelvis in the midline; these structures can be imaged with ultrasound but are indistinct.
- The cervix is located cranial to the vagina approximately 20 cm cranial to the anal sphincter and can be identified as a heterogeneous, generally hyperechogenic region with a rectangular outline.
- The uterus is roughly T- or Y-shaped; therefore when using a linear ultrasound transducer the outline of the uterine body generally appears rectangular (the transducer is in a sagittal plane) whilst the outline of the uterine horns appears circular (the transducer whilst orientated in the sagittal plane is positioned in a transverse plane with respect to the uterine horn).
- The uterus has a central, homogeneous, relatively hypoechoic, region surrounded by a peripheral hypechoic layer.
- The echogenicity of the endometrium and the uterine cross-sectional diameter vary during the estrous cycle; during oestrus the diameter increases and the uterus becomes increasingly hypoechoic, with central radiating hyperechoic lines which are typical of endometrial oedema.
- The proximal uterine horns are of smaller diameter than the uterine body.
- The ovaries can be located by tracing the uterine horns laterally.
- Various sections of the ovaries are usually examined by rotation of the transducer; sections are usually taken from a medial position, and sequential sections of the ventral, mid, and dorsal portions of the ovaries are examined.
- Ovaries usually contain follicles (which are anechoic), and may contain luteal structures (which are relatively echogenic – varying shades of greywhite); the ovarian stroma may be difficult to appreciate since it may be surrounded by these structures, although it is generally hypoechoic in appearance.

*Diagnosis of early pregnancy.*
The early conceptus can be imaged when there is sufficient yolk-sac fluid to be imaged. The yolk sac appears as an anechoic structure which, in early pregnancy, is spherical. There is usually a small echogenic region on the dorsal and ventral poles of the conceptus; this is a normal ultrasound artifact.

- From ten days after ovulation the conceptus can be imaged; it appears as a spherical anechoic structure approximately 2mm in diameter.
- The conceptus rapidly increases in diameter to reach approximately 10mm in diameter 14 days after ovulation. The outline remains circular (spherical) presumably because of the thick embryonic capsule.
- Until day 16 the conceptus is mobile and may be identified either within the uterine horns or the uterine body. This mobile phase is important for the maternal recognition of pregnancy.
- During pregnancy diagnosis, careful attention to imaging of the entire uterus is required; the transducer should be moved slowly from the tip of one uterine horn to the other, and then caudally towards the cervix.
- Trans-uterine migration usually ceases by day 17, and the conceptus becomes fixed in position at the base of one uterine horn.
- From day 17 until day 28 the increase in conceptus diameter is slowed.
- After fixation the conceptus rotates so that its thickest portion, the region of the embryonic pole, assumes a ventral position.
- The uterine wall adjacent to the dorsal pole of the conceptus becomes thickened.
- The conceptus generally retains a spherical outline until approximately 17 days after ovulation after which time it may be deformed by pressure from the transducer; it may then appear triangular or flattened in outline.
- The embryo may be imaged from approximately 21 days after ovulation when it appears as an oblong-shaped hyperechoic structure adjacent to the ventral pole of the conceptus.
- A heartbeat is commonly detected within the embryonic mass from approximately 22 days after ovulation. It appears as a rapidly-flickering motion in the central portion of the embryonic mass.
- Growth of the allantois lifts the embryo from the ventral position and the allantois per se may be identified from day 24, when it appears as an anechoic structure ventral to the embryo.
- The size of the allantois increases and that of the yolk sac is gradually reduced until at approximately 30 days after ovulation they are similar in volume.
- From day 30 onwards it is possible to image the amnion surrounding the developing embryo.
- At 35 days after ovulation the embryo is approximately 15mm in length and the allantois is three times the volume of the yolk sac.
- By days 38–40 the fetus is positioned adjacent to the dorsal pole of the conceptus.
- At day 40 the yolk sac is almost completely absent, and the umbilicus, which attaches to the dorsal pole, can be imaged.
- A reliable relationship exists in early pregnancy between size of the conceptus and gestational age.
35 days pregnancy

40 days pregnancy

45 days pregnancy

Ovary at 45 days of pregnancy

Ovary has Graffian follicle

Uterus during estrous phase

Late pregnancy - A ribs of fetus

Endometrial cyst
**Diagnosis of late pregnancy:**

Late examinations using ultrasound may not be necessary since pregnancy diagnosis is simple by palpation at this time. However, ultrasound is being used increasingly to confirm normal fetal development, and to assess fetal well-being.

- The fetal skeleton becomes visible during late pregnancy; the head, spinal column and ribs produce intense reflections that are easily identifiable.
- From 150 days onwards it is not always possible to image the entire fetus using high-frequency transducers because of their short depth of penetration. The dorsal portion of the fluid-filled uterus can always be imaged and the fetus may be seen by using a lower-frequency transducer either transrectally or trans-abdominally.
- From eight months of pregnancy it may be difficult to image more than a small portion of the fetus because of its large size.
- In the last trimester the amniotic cavity is increased in volume, and the amniotic fluid contains multiple, small, echogenic particles.

**Time of ultrasound examinations for pregnancy:**

**First examination at day 14–16**
- The aim is to diagnose pregnancy and to ensure that the pregnancy is a singleton.
- The conceptus is spherical and anechoic with a dorsal and ventral specular echo.
- Examine the ovaries and count the number of luteal structures (multiple conceptuses nearly always originate from separate ovulations, and therefore result in multiple luteal structures).
- Multiple conceptuses may lie adjacent to each other or be separate.
- Conceptuses are mobile and careful examination of the entire tract is necessary to identify them.
- If multiple conceptuses are identified they can be managed, since they are not fixed in position until after day 16.
- Multiple conceptuses can be separated and the smaller one crushed.
- The mare should be examined 2–3 days later if a twin has been crushed.

**Second examination at day 21–22**
- The aim is to confirm the diagnosis of pregnancy, ensure that the pregnancy is a singleton and monitor the growth of the conceptus.
- Conceptus is fixed at base of one uterine horn.
- The conceptus can be distinguished from a uterine cyst by the presence of an embryo.
- Identification of a heartbeat confirms embryonic viability.

**Third examination at day 35**
- The aim is to confirm the diagnosis of pregnancy, to monitor viability of the conceptus and to make any final decision before formation of the endometrial cups and the secretion of equine chorionic gonadotroph.

**Protocol for ultrasound examination:**

**First examination at day 14–16**
- If there is no suspicion of multiple conceptuses (single ovulation; single CL):
  - Single conceptus imaged. re-examine at day 21;
  - No conceptus imaged. check ovulation date; if correct inject PG, if uncertain re-examine in two days’ time.
- If there is a suspicion of multiple conceptuses (multiple ovulations; multiple luteal structures):
Single conceptus seen. re-examine in two days; if still single conceptus, re-examine at day 21;

Multiple conceptuses seen. PG;
(1) or do not treat (little point as only 14 days pregnant);
(2) or crush the smaller conceptuses. re-examine in two days;
– if single remains. re-examine at day 21
– if all conceptuses lost. inject PG.

Second examination at day 21–22.
• Expect to see increased size of conceptus.
• Anechoic yolk sac.
• Embryo (with heartbeat) positioned at ventral pole.
• If embryo not identified, it may indicate a conceptus that is underdeveloped for its age. Such conceptuses often fail, so this finding may necessitate termination of the pregnancy, using PG at this stage.

Third examination at day 35
• Expect to see small volume yolk sac, with embryo at the dorsal pole.
• Large volume of allantois.
• The amnion may also be imaged.
• Last time for interventions before endometrial cups secrete eCG.

NB: Pregnancy may be terminated using PG after this time, but there is rarely a return to a fertile oestrus within the same breeding season.

Diagnosis of fetal sex:
Fetal sex may be accurately diagnosed 55–80 days after ovulation.
• Interpretation is difficult unless the operator is experienced.
• Diagnosis relies upon identifying the position and appearance of the genital tubercle. This is best done 55–75 days after ovulation.
• It is important to identify three structures:
  (1) Genital tubercle;
  (2) Umbilicus;
  (3) Tail.
• The genital tubercle is a bilobed structure approximately 2mm in diameter.
• In the male, the distance between the genital tubercle and the umbilicus is less than the distance between the genital tubercle and the tail.
• The opposite relationship exists in the female.
• Trans-abdominal ultrasound may be used for sex determination after nine months’ gestation.

Uterine cysts – structures that may mimic pregnancy:
Endometrial glandular or lymphatic cysts are not uncommon in the mare. They are fluid filled and therefore appear anechoic when imaged with ultrasound.
• Cysts commonly have a fine, moderately-echogenic wall which may not be fully appreciated unless there are multiple cysts or there is free uterine fluid.
• Cysts may range from several millimetres to several centimetres in diameter.
• Luminal cysts may be confused with early conceptuses.

To avoid these problems, it is prudent to record the size, shape and position of uterine cysts prior to breeding (at the first ultrasound examination of the year); cysts do change in their appearance during the year, however their position is constant. If a cyst has not previously been mapped it may be diagnosed as a cyst because:
• Cysts are often irregular in outline;
• Cysts are frequently lobulated;
• Cysts do not always have dorsal and ventral pole specular echoes;
• Cysts do not change position;
• Cysts do not increase in size;
• Large cysts do not contain an embryo, whilst this can be seen in a conceptus after day 21.

**PREGNANCY AND ITS DETECTION IN THE COW:**
A variety of different methods has been, and is still, used to detect the presence or absence of pregnancy in the cow. These range from the identification of substances that are present in body fluids using laboratory assays, and from different ultrasound modes, to simple clinical methods such as transrectal palpation; the latter has been the most ubiquitously used method for the last 70 years.

<table>
<thead>
<tr>
<th>Method</th>
<th>Earliest time</th>
</tr>
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<tbody>
<tr>
<td>Early pregnancy factor (EFP)/early conception factor (ECF)</td>
<td>3 days</td>
</tr>
<tr>
<td>Realtime ultrasound (direct imaging)</td>
<td>13 days</td>
</tr>
<tr>
<td>Failure to return to oestrus and persistence of corpus luteum</td>
<td>21 days</td>
</tr>
<tr>
<td>Progesterone concentration in plasma and milk</td>
<td>21–24 days</td>
</tr>
<tr>
<td>Assay of pregnancy-specific protein B (PSFB)</td>
<td>24 days</td>
</tr>
<tr>
<td>Palpation of the allantochorion (membrane slip)</td>
<td>33 days</td>
</tr>
<tr>
<td>Unilateral cornual enlargement and disparity in size, thinning of the uterine wall, fluid-filled fluctuation of enlarged horns</td>
<td>35 days</td>
</tr>
<tr>
<td>Palpation of the early fetus when the amnion loses its turgidity</td>
<td>45–60 days</td>
</tr>
<tr>
<td>Palpation of the carnules/cotyledons</td>
<td>80 days</td>
</tr>
<tr>
<td>Hypertrophy of the middle uterine artery until presence of fremitus</td>
<td>85 days</td>
</tr>
<tr>
<td>Oestrone sulphate in blood or milk</td>
<td>105 days</td>
</tr>
<tr>
<td>Palpation of the fetus</td>
<td>120 days</td>
</tr>
</tbody>
</table>

*Failure to return to oestrus and persistence of the corpus luteum.* Failure of regression of the CL at about 21 days, as determined by transrectal palpation, provides a method of anticipating that the cow is probably pregnant. It is seldom used as a practical procedure and there are reasons for the CL persisting in the absence of pregnancy. Rectal examination at about this time in an individual which was close to or at, oestrus would demonstrate the presence of a turgid, coiled uterus and a mucoid vaginal discharge.
Mammary glands:
Mammary changes during pregnancy are best observed in primigravida. The teats of the pregnant heifer begin to enlarge about the fourth month, and with a little experience it is an easy matter to distinguish them from those of the non-pregnant or early pregnant animal. From the sixth month the mammary glands become more firm to the touch and their enlargement can be seen. Hypertrophy is progressive and is particularly marked during the terminal month. As parturition approaches, the glands become grossly enlarged and oedematous and the teats take on a waxy, tumefied appearance. The abdominal wall, particularly in the region of the umbilicus, may also become swollen by oedema. In the dry milk cow, mammary enlargement occurs during the last 14 or so days of pregnancy. After the fourth month a honey-like secretion may be withdrawn from the teats of pregnant heifers.

Abdominal ballottement:
This is often possible as early as 7 months of gestation in some small breeds such as the Jersey. However, in some fat cows of large breeds it is sometimes impossible even at term. The method involves fairly vigorous pummeling of the ventral abdomen and flank with clenched fists. The object is to push the fetus, which is floating in the fetal fluids, away from the body wall and then identify it as it swings back against the fist which is kept pressed against the abdominal wall.

Laboratory methods:
Identification of early pregnancy factor/early conception factor.
Early pregnancy factor (EPF) is an immunosuppressively coprotein associated with pregnancy. It was first identified in the mouse and subsequently in a large number of domestic species; in the cow it has a molecular weight of 200 000. Commercially available test kits are available which use the 'dip-stick' principle and can detect early conception factor (ECF) in serum and milk from as early as 3 days after artificial insemination, although more accurate results are obtained if samples are taken later at 7 to 8 days. The test, which is still in the developmental stage, obviously has important practical application in the early identification of the non-pregnant cow in the luteal phase after an unsuccessful insemination; thus the cow can be treated with PGF2α to induce a premature oestrus, when it can be rebred, saving time.

Assay of pregnancy-specific protein B.
This protein has been identified in the maternal serum of cows from 24 days of gestation; the concentration is measured by radio-immunoassay. It is secreted by the binucleate cells of the trophoblastic ectoderm, and thus its presence can be used to confirm pregnancy. However, since it has a long biological half-life it can also be identified in serum for many weeks postpartum; for the same reason, false positives can occur after embryonic or fetal death. At present, it can only be measured by radioimmunoassay (RIA) but, with the development of suitable enzyme-linked immunosorbent assay (ELISA) methods, it could well become an ‘on farm’ diagnostic test.

Progesterone concentration in plasma and milk:
Since the CL persists as a result of the pregnancy, if a blood sample is taken at about 21 days after the previous oestrus, progesterone levels remain elevated. If the cow is not pregnant and is close to or at oestrus then the progesterone levels will be low. Progesterone is very soluble in milk fat there were higher concentrations per unit volume in milk than in the blood or plasma. Progesterone concentrations in the milk were assayed using radio-immunoassay; it is an effective method of measurement but requires the use of radio-isotopes and the equipment to measure radioactive emissions. A number of qualitative ‘cow-side’ tests have been developed which can
be used on the farm and hence enable the herdsperson to obtain a result within 1 hour of collecting the milk sample. All the necessary reagents and equipment are provided in kit form. Semiquantitative or fully quantitative tests are also available but these are designed for use in a veterinary practice laboratory, since they require a minimum amount of equipment and some expertise. Both tests are based on ELISA.

**The reasons for false negative results are:**

1. Mistaken identity of the animal either on the farm or in the laboratory.
2. Milk storage problems due to excessive heat or ultraviolet light.
3. Low progesterone production by the CL.
4. Inadequate mixing of milk so that a low fat sample is obtained.

The reasons for false positive results are:

1. Cows with shorter than average interoestrus intervals, i.e. 18 days. When milk samples are taken 24 days after service or artificial insemination, if the cow is not pregnant she will already be in the early luteal phase of the next cycle.
2. Embryonic death, if it occurs after the day when the milk was collected.
3. Luteal cysts which produce progesterone.
4. Incorrect timing of insemination. Thus if a milk sample is taken 24 days after the cow was incorrectly inseminated in early or mid-dioestrus, and the intervening oestrus has not been observed, then she will be in the subsequent dioestrus with a functional CL and elevated milk progesterone concentrations.
5. Pathological prolongation of the life span of the CL such as persistent CL.

**The main advantage of the milk progesterone test is that it identifies those cows that are not pregnant before it is possible to do so by other methods such as rectal palpation. Cows which are found to be pregnant at 24 days should be examined at a later date by transrectal ultrasonography or palpation. The on-farm tests can be used as early as 19 days after service since a low progesterone concentration at this time is highly indicative of non-pregnancy and thus the first return to oestrus can be anticipated.**

**Oestrone sulphate in milk**

Oestrone sulphate is quantitatively one of the major oestrogens in the milk of pregnant, lactating cows. During gestation the concentration increases gradually so that after day 105, it is present in the milk of all pregnant animals, whereas in non-pregnant individuals it is low or undetectable; the source of the hormone is the fetoplacental unit.

**Transrectal palpation**

*Palpation of the amniotic vesicle;* this method involves the palpation of the amnion towards the end of the first month of pregnancy. It proceeds briefly as follows. The bifurcation of the uterine horns is located, and then the horns are uncoiled and gently palpated along their entire length between the thumb and middle two fingers. The amniotic sac can be felt as a distinct, round, turgid object 1–2 cm in diameter floating in the allantoic fluid. The vesicle should not be compressed directly but gently pushed backwards and forwards.

*Palpation of the allantochorion (membrane slip);* this method is dependent upon the facts that in the cow, attachment of the allantochorion to the endometrium occurs only between the cotyledons and the caruncles, and that the intercotyledonal part of the fetal membrane is free. The method is as follows. Identify the bifurcation of the uterine horns, pick up the enlarged, gravid horn between thumb and either index or middle finger just cranial to the bifurcation and gently squeeze and roll the whole thickness of the horn. The allantochorion will eventually be identified as a very fine structure as it slips between the thumb and finger before the uterine and rectal walls are lost from
the grasp. It is important in the early stages of pregnancy to grasp the whole width of the horn because as the allantochorion is very thin at this stage the structure that can be more readily identified is the connective tissue band which contains the blood vessels supplying the allantochorion.

**Unilateral cornual enlargement:** unless there are twin conceptuses, one in each horn, it is possible to detect a difference in the size of the two horns. This is largely due to the presence of fetal fluids, in particular allantoic fluid, which gives the uterine horn a fluctuating feel with good tone.

**Palpation of the early fetus:** At about 45–50 days of gestation the amniotic sac becomes less turgid, and it is sometimes possible to palpate directly the small developing fetus. This should be done with care.

**Palpation of caruncles/cotyledons (placentomes):** Caruncles/cotyledons first become recognizable by rectal palpation at 10–11 weeks as roughened elevations when the fingers are passed back and forth over the surface of the enlarged gravid horn. From about 3 months they can be identified as discrete structures in the midline, about 8–10 cm in front of and over the pelvic brim, by pressing down upon the uterine body and base of the horns. In the early stages it is difficult to identify them as distinct, individual structures.

**Hypertrophy of the middle uterine artery and development of fremitus:** the artery runs in the road ligament, along a tortuous course, passing downwards, forwards and towards the midline over the pelvic brim close to the junction between pubis and ileum. Usually, it is identified 5–10 cm lateral to the cervix. Inexperienced persons sometimes confuse it with the iliac and obturator arteries, but the middle uterine artery is mobile and it can be encircled within the thumb and forefinger. During the period 100–175 days cases will frequently be met which ‘throb’ but later pulsate. It is probable that the degree of pressure applied to the artery influences the feeling imparted to the fingers; light pressure detects a ‘thrust’, whereas a pulse wave is apparent to heavy pressure. The ‘thrust’ generally becomes continuous after day 175. During the terminal stages of gestation the uterine arteries become greatly hypertrophied and tortuous; they can be distinctly felt, with the thickness of a pencil, with a continuous, tremor-like pulse, laterally situated 2 cm or so in front of the cranial border of the iliac shaft.

**Palpation of the late fetus:** Palpation of the fetus, either per rectum or by abdominal ballottement, is diagnostic of pregnancy.

**Accuracy of pregnancy diagnosis by rectal palpation:**
The most likely reason for making a false positive diagnosis is subsequent embryonic or fetal death. Other reasons for false positives are incomplete uterine involution, pyometra, mucometra and hydrometra and failure to retract the uterus. The reasons for false negatives are incorrect recording of the date of service or artificial insemination, so that when the cow is examined she is pregnant but a cycle length earlier than expected and incomplete retraction of the uterus.

**Vaginal examination:**
Examination may be manual or visual. In the latter case, an illuminated speculum is used. The condition of the vaginal mucous membrane does not afford definite clinical evidence of pregnancy, for the degree of ‘dryness’ and blanching which occur during the dioestrus period are very similar to those of pregnancy. It is to the external os of the cervix that attention is directed. During pregnancy the secretion of the cervical glands becomes gelatinous and tough, forming a plug for sealing the canal. In many cases the seal covers or protrudes from the external os. It has developed by day 60.

**Ultrasonographic methods:**
Using a 7.5 MHz transducer, were able to confirm pregnancy as early as 9 days, whilst, using a 5 MHz transducer were able to do so at 12 and 14 days in heifers before the blastocyst had elongated. By 17 days the blastocyst will have elongated and extended into the contralateral horn; this can usually be easily identified by 26 days.

**Fetal electrocardiography:**
Fetal electrocardiography has been noted as a method of pregnancy diagnosis. It is not applicable before 5 months of gestation, but it might have application for the diagnosis of multiple pregnancies.

**PREGNANCY AND ITS DETECTION IN THE EWE AND DOE:**

**Management methods:** Traditionally the method used by shepherds is the observation that ewes, which have been marked by a ‘keeled’ or ‘raddled’ ram, fail to be marked again within 16–19 days. Beyond 100 days of gestation the fetus may be palpated through the abdominal wall, and development of the udder is then obvious in primipara. The best way to ballotte the fetus is to have the ewe standing normally and to lift the abdomen repeatedly immediately in front of the udder; the fetus can be felt to drop on to the palpating hand.

**Rectal Abdominal Palpation:**
This is a simple, cheap, and quick technique to diagnose pregnant ewes. It consists of inserting a lubricated rod into the rectum of a ewe that is lying on its back. One hand is placed on the abdomen of the ewe while the other hand manipulates the rod toward the hand that is over the abdomen. The technique is not indicated for early pregnancy diagnosis because the sensitivity is reportedly low (59 percent sensitivity between days 21 to 55). With the advance of gestation, at 85 to 109 days after breeding, it has a reported accuracy of 100 percent. However, some authors haven’t had the same success rate, indicating that operator experience with this technique is very important. A serious disadvantage of the technique is the risk of rectal injury to the ewe and the induction of abortion.

**Ultrasonographic methods:** the fetal pulse detector (Doppler) has been used to diagnose pregnancy in ewes, and two types of probe are available. The external probe is applied to the skin surface of the abdomen just cranial to the udder. The fleece in this region is sparse and with transmission gel applied to the end of the probe it is slowly moved over the surface. The ewe can be restrained either standing or sitting on her haunches. Characteristic sounds indicate the presence of the fetal heart (‘tack, tack, tack’) or vessels (‘swish, swish, swish’); the frequency greatly exceeds that of the mother’s heart rate, except in late gestation when the fetal heart rate is reduced. Between 40 and 80 days of gestation the accuracy of detection is no better than 60%. However, after 80 days, with a reasonable amount of practice, it is over 90% accurate and it takes an average 3 or 4 minutes per ewe to make a diagnosis. Using a rectal probe an accuracy of 97% between 35 and 55 days after mating. A B-mode ultrasound sector transducer probe, using the Tran abdominal approach, has proved to be an accurate
and rapid method of not only differentiating pregnant from non-pregnant ewes but also accurately determining fetal numbers.

**Transabdominal Palpation:**
The presence of a fetus is detected by manual palpation of the ewe’s abdomen. This is more easily accomplished with the ewe in the seated position. The operator’s hands are placed on both sides of the abdomen. With one hand pressing on one side of the abdomen, the fingers of the other hand palpate the abdomen in search of fetuses. The presence of lambs is felt as a free floating mass that bounces against the operator’s fingers. Although simple and inexpensive, the technique requires training and is limited to the last two months of gestation. The accuracy of the technique varies with the experience of the operator, starting at 80 percent and reaching 90 percent in thin ewes that have been recently shorn. The accuracy can be increased if the method is used in association with other techniques such as udder examination.

**Udder Examination (Wet and Dry Techniques):**
This is an indirect method of detecting pregnancy in ewes. It can be performed during late gestation and can have a high accuracy rate if associated with other techniques such as abdominal enlargement and transabdominal palpation. It is best performed during the last month of gestation when ewes start their udder development. This technique also yields the best results if the breeding (lambing) season is short; otherwise the udder inspection needs to be performed twice with a three-to-four-week interval. At this stage the udder is firm and enlarged and feels warm. Colostrum can be milked at this stage to confirm pregnancy and differentiate from mastitis or fat open ewes that have been fed estrogenic rich clover. These animals have an enlarged udder that is soft and cold to the touch and their secretions can vary from a watery fluid to thick white milk. In contrast, colostrum should be thick and cream-colored or it can be thick and yellow with a honey appearance. At this stage, ewes identified as pregnant can be separated from the flock for adequate management. It is advisable to do a final check within the last week of the lambing season to identify/cull the ewes that did not conceive during the breeding season. This technique does not allow the determination of the lambing date or the number of fetuses.

**Vaginal biopsy:** the stratified squamous epithelium of the vaginal mucosa is sensitive to the hormonal changes that occur during the estrous cycle and pregnancy. There is no doubt that the difference in the histological appearance is greater between oestrus and pregnancy than between dioestrus and pregnancy. The diagnosis depends on the number of layers of vaginal epithelial cells, which in turn relates to the endocrine state; thus during pro-oestrus, when oestrogen is dominant, a rapid proliferation of the stratum germinativum occurs, so that at oestrus there are up to 20 layers. From the end of oestrus and throughout the luteal phase, when progesterone is dominant, the depth of vaginal epithelium falls, so that by day 11 or 12 there are only three or four irregularly arranged layers and only two or three layers in late dioestrus. With the onset of pregnancy progesterone domination continues, and by day 26 the typical histological picture is two parallel rows of epithelial cells with condensed darkly staining nuclei. This pattern persists until the final 3 weeks of gestation. Sections taken erroneously from the cervix or posterior vagina are unsatisfactory for diagnosis.

**Estimation of plasma progesterone:** Since there is a decline in progesterone concentrations in the peripheral blood from about day 16 in nonpregnant cyclical animals, estimation of progesterone concentrations from this time after service would be worthwhile. Values of progesterone in the plasma ≥7.5 ng/ml were indicative of pregnancy. In lactating ewes it is also possible to determine the progesterone levels in
milk. Plasma and milk progesterone values in pregnant sheep 18–22 days after mating were similar (3.7 ng/ml), whereas in non-pregnant ewes they were 1 ng/ml. 

**Rosette inhibition tititer(T) test:** this is an established test for determining the immunosuppressive potential of antilymphocyte serum which has been applied to determining the presence of an ‘early pregnancy factor’ (EPF) in ewes. 

**Radiography:** Both dorsoventral and lateral radiographs can be taken. Fetuses were detectable from 70 days of gestation. 

**Peritoneoscopy and laparoscopy:** Some authors obtained 91% accuracy of pregnancy detection between 17 and 28 days by means of direct inspection of the uterus and ovaries with a laparoscope, using general anesthesia. 

**PREGNANCY AND ITS DETECTION IN THE BITCH:** 

The main problem in diagnosing pregnancy in the bitch is that overt pseudopregnancy is very common, the degree varying from individual to individual. The deposition of abdominal and subcutaneous fat during pregnancy is often marked. It is storing of fat for the subsequent lactation, for it is generally lost again during the period of nursing. The gravid uterus and its contents cause no appreciable increase in body weight during the first 5 weeks. From this point body weight rapidly increases according to the number of fetuses. The increase will vary from 1 kg in a 5 kg bitch to 7 kg or more in one of 27 kg, but by the time body weight has become a guide there are other very definite signs of pregnancy. 

**Mammary glands:** 

Characteristic changes occur in the mammary glands. Unfortunately, similar but less definite changes may occur during pseudopregnancy. These changes are more easily recognized in primigravida. At about day 35, in unpigmented skins, the teats become bright pink, enlarged and turgid; they protrude. This condition persists until about day 45, when the teats become larger still but softer and tumefied. 

**Abdominal palpation:** 

The ease and accuracy of abdominal palpation will depend upon the following factors:

1- the size of the animal: the smaller, the easier
2- Its temperament: whether palpation is resisted
3- The period in gestation at which examination is made
4- the number of fetuses in uterus
5-whether the bitch is of normal size or grossly fat

**Radiography:** Radiography is a particularly useful diagnostic aid in the terminal stages of pregnancy, especially in the obese dog where a differential diagnosis from pseudopregnancy is required or in bitches with a single puppy that may have suffered prolonged gestation. It is also very valuable in dystocia cases to disclose the presence of retained puppies and the disposition of a presenting puppy. 

**Ultrasonographic methods:** Using the Doppler method with an external transducer probe placed on the abdominal wall adjacent to the mammary glands, fetal heart sounds were detected as early as 29 days of gestation. 

**Measurement of serum proteins:** Serum fibrinogen concentrations during pregnancy can be used for pregnancy diagnosis, with peak values occurring 4–5 weeks after mating. Since this phenomenon did not occur at the corresponding stage of the luteal phase in non-pregnant bitches, it can be used as a method of detecting pregnancy. This is likely to be produced in response to the implantation of the embryo causing tissue damage. There are always dangers that false positives may arise if there is infection and inflammation elsewhere.
**Measurement of hormones in the peripheral circulation:** Elevated progesterone concentrations in the peripheral circulation are used to detect pregnancy in the polyoestrous species, they are of no value in the bitch because of the prolonged luteal phase (pseudopregnancy) in non-pregnant animals.

**PREGNANCY AND ITS DETECTION IN THE CAT:**

Ovulation occurs 23–30 hours after mating, and serum progesterone. Concentrations rapidly increase from the baseline of under 10 nmol/l to reach peak values of around 100 nmol/l between the first and fourth weeks of pregnancy. Cats are unusual in that queens may continue to display estrous behavior and accept mating, even though ovulation may have occurred and there is significant production of progesterone. At 3–4 weeks of pregnancy, hyperemia of the teats occurs. This is particularly prominent in maiden queens. It is a progesterone-dependent phenomenon and is also seen in pseudopregnancy. Cats lend themselves particularly well to pregnancy diagnosis by abdominal palpation. This is most satisfactorily performed 16–26 days after mating when conceptuses are readily identifiable as individual turgid spherical swellings. Pregnancy may be confirmed as early as 13 days after mating, but, at this stage, the conceptuses may be confused with faecal boluses. After 6 weeks, the conceptual swellings increase markedly in size, elongating and merging, thus making palpation more difficult. However, by this stage, there will usually be significant abdominal enlargement. B-mode ultrasound enables pregnancy diagnosis to be confirmed by demonstration of an enlarged uterus as early as the first week of pregnancy and, more reliably, by identifying the gestational sac from the second week.
A number of factors can influence embryonic development. The conceptus may be exposed to harmful agents during the pre-attachment, embryonic or fetal stages of development, and vulnerability to these agents varies with these different stages. For example, during the pre-attachment stage the embryo is very resistant to teratogens and the zona pellucida is an efficient barrier to many viruses. By contrast, the embryonic stage, with rapid cell growth and differentiation, is most susceptible to teratogens. Furthermore, each organ has a critical period of development.

### Fertilisation Failure and Embryonic/Fetal Loss:

In polyoestrous species embryonic loss can be suspected when there is an irregular extension of the interoestrus period. Furthermore, in polytocous species like the pig, embryos may be lost without termination of pregnancy. Fetal loss occurs before fetal maternal recognition, and therefore does not involve the elongation of the life of the corpus luteum, is referred to as early embryonic death (EED). Loss after the life of the corpus luteum has been extended is termed late embryonic death (LED). In mares, most loss occurs between days 10 and 14 post-service; in beef cattle it is before day 15 post-service. In sheep most losses occur between days 15 and 18 post-service. Failure of maternal recognition of pregnancy will cause early embryonic loss, and the animal returns to oestrus at normal intervals (<25 days). Late embryonic loss occurs after maternal recognition of pregnancy when the animal may show their next heat 25 to 40 days after the previous heat.

### Causes of Embryonic/Fetal Loss:

1. **Extreme Environmental Temperatures.** Cattle that are mated in a high environmental temperature and kept there after service exhibit a high rate of embryonic death. The dominance of the large preovulatory follicle is suppressed by heat stress, and the steroidogenic capacity of theca and granulosa cells is compromised. Progesterone secretion by luteal cells is lowered during the summer in hot climates. Cows subjected to chronic heat stress this is also reflected in a lower plasma progesterone concentration. Heat stress has also been shown to impair oocyte quality and embryo development, and increase embryo mortality. In addition to the immediate effects of heat stress, delayed effects have also been detected. These include altered follicular dynamics, suppressed production of follicular steroids and lower quality of oocytes and developing embryos. This may explain why poor fertility may persist for some time after periods of heat stress. Poor pregnancy rate is a problem when European cattle are introduced into hot countries where they are exposed to ambient temperatures above 30°C; it is quite likely that increased embryonic death is part of the reason. There is little doubt that genetic factors are involved in this as in other aspects of heat tolerance. Crosses between indigenous heat tolerant breeds and European breeds are more heat tolerant than the imported animals and they are more fertile. The improved fertility appears to be the result of the dam’s enhanced ability to control body temperature rather than an inherited ability of the embryo itself to tolerate high intrauterine temperatures. The position is less clear with extreme cold, but there are indications that a corresponding adverse effect occurs. The problem could arise during unusually cold periods in temperate climates where housing tends to provide cover rather than warmth.
2-Metritis/endometritis: Metritis or endometritis in varying degrees of intensity is a common condition causing infertility in cattle. Where caused by infection it can be divided into non-specific, exemplified by *Arcanobacterium pyogenes* infection, and specific, typified by *Tritrichomonas fetus* and *Campylobacter fetus* infection. There are also a number of infections that are difficult to classify such as bovine herpes virus-1 (BHV-1), *Ureaplasma* spp. and *Haemophilus somnus*. Non-specific metritis is the result of either massive infection or of the infective organisms taking advantage of a deficient uterine defence mechanism, usually caused by damage at and after calving. Non-specific infection can be facilitated by the synergistic action of different organisms, for example *A. pyogenes* and *Fusobacterium necrophorum*. Specific infections colonize the undamaged uterus. Two important specific infective agents are *C. fetus* and *T. fetus*. Campylobacteriosis is spread venereally and causes a mild endometritis in infected females that have not had previous experience of the condition. It has been shown in slaughter experiments that in infected animals fertilization rate is normal and that the infertility is due in the main to embryonic death within three weeks of conception. Loss of the embryo is likely to be due to interference with the uterine environment. Another infectious agent that is introduced from the vagina into the uterus at insemination, but not at natural service, is *Ureaplasma*, which causes a purulent metritis and infertility. *Haemophilus/Histophilus* also causes vaginitis and reduced fertility. For detailed discussion of a wide range of infectious agents.

**Infectious conditions can cause infertility in at least four ways:**

1- The febrile reaction raises the temperature of the uterus. Bluetongue is an example of a disease that causes a high temperature resulting in loss of the embryo at about the time of hatching from the zona pellucida, about day 10–12 after service.

2- The organism infects the uterus and causes metritis, which presumably interferes with embryo nutrition and may also infect the embryo. Examples are BHV-1 virus and *Chlamydiales* infections. It is likely that, in general, mild endometritis causes embryonic death whereas in cases of purulent metritis there may be interference with spermatozoa survival and thus fertilization failure.

3- Infection of the conceptus can cause its death. The thought that embryo transfer could transmit infectious diseases from the sire or the dam is worrying. In theory, bacterial and fungal infections are less likely than viral infections to be carried by embryos. From experimental studies with many different viruses it appears that if the zona pellucida is intact and the embryo is washed properly, there is little danger of the transmission of viral infections by embryo transfer. However, the advent of in vitro technology may increase the risk of disease transmission due to differences in the zona pellucida of *in vitro* derived embryos, enabling easier adsorption of pathogens, and due to the use of biological products for culture which may be contaminated with pathogens.

4- Endotoxins produced by Gram-negative infections can increase PGF2a production and cause premature luteolysis.

3-Maternal endocrine environment: low plasma concentrations of progesterone resulted in the development of a stronger luteolytic signal. This was taken as an explanation for the fact that cows with lower plasma concentrations of progesterone post insemination are more prone to embryo loss than those with higher progesterone levels. Interferon tau (IFN-t) is a protein produced by the embryo that acts locally within the uterus to block luteolysis and maintain the corpus luteum; it prevents PGF2a secretion by inhibiting the development of oxytocin receptors in the endometrium. Successful maternal recognition of pregnancy in cows depends on the
presence of a sufficiently well developed embryo producing sufficient quantities of IFN-\(\text{t}\), which is, in turn, dependent on an appropriate pattern of maternal progesterone secretion. The maternal endocrine environment, and particularly maternal progesterone levels within the first one to two weeks after insemination, is likely to be extremely important in determining whether an embryo signals its presence to the dam and survives or is lost as the cow returns to oestrus.

**4- Aged gametes:** Fresh chilled semen ages after several days and the inseminated cows have a lower pregnancy rate almost certainly due to both reduced fertilization rate and increased loss of embryos. There is no evidence of adverse effects from ageing of frozen semen stored in liquid nitrogen. Fertilization of ageing eggs following ovulation of persistent dominant follicles is also likely to result in an increased amount of early embryonic death.

**5- Local trauma:** This cause of loss affects the late embryo and early fetus. One source of local trauma to the pregnant uterus is the hand of a person carrying out manual pregnancy diagnosis, or some other palpation of the uterus. In one study the average loss was 2.82 per cent of cows diagnosed pregnant. The fetal loss rate of 9.5 per cent in cows diagnosed pregnant on days 42–46. The technique, which was carried out on two days, involved palpation of fetal fluid, identification of the amniotic vesicle and slipping of the chorioallantoic membrane. However, with good transrectal ultrasound examination technique such losses should now be largely preventable.

**6- Genetic factors:** In some cattle, in the process of cell division, translocation of parts of certain chromosomes without loss of genetic material has taken place, a condition that is passed on to future generations. These individuals can be identified by cytogenetic examination of leukocytes. When semen from bulls with a translocation is used for insemination there is a slight increase in the incidence of return to service, which is believed to be the result of embryonic death, presumably because of lack or excess of some genetic material due to abnormal division at meiosis. It is also probable that many genetically abnormal embryos are lost early in development, with the advantage that the dam can return to normal breeding at the earliest opportunity.

Some factors almost certainly cause an increased return to service via an unknown mechanism. An example is the etiological relationship between loss in body condition from calving to service and associated poor pregnancy rate. The possible sites where inadequate nutrition may have detrimental effects on reproductive function include:

1. The hypothalamus/pituitary gland to impair gonadotrophin release.
2. The ovaries, possibly resulting in altered follicular growth patterns and reduced quality of oocytes and subsequent reduced embryo survival.
3. Inadequate uterine environment resulting in impaired embryo survival.

Genetic factors causing embryonic loss include single-gene defects, polygenic abnormalities and chromosomal anomalies. A few single-gene mutations are lethal and result in the death of the conceptus. If the gene is dominant, a single copy may be sufficient to cause death, whilst in other instances it is only the homozygous state that is lethal (e.g. the dominant Manx gene (M) in the cat). Recessive genes only exert their effect in the homozygous state. Not all genetic defects are lethal. Some abnormal fetuses survive to term, which is biologically and economically wasteful. Therefore, carrier animals should be eliminated from the breeding programme wherever possible. Traditional methods of test mating to identify animals which are carriers of a recessive gene (backcross to the recessive) are laborious and in some cases not justified on welfare grounds. The mule is a cross between a female horse and a male
donkey, and the hinnies are a cross between a female donkey and a male horse. The males of both crosses show abnormalities of chromosome pairing at the pachytene stage of meiotic prophase, and little or no mature spermatozoa are produced. Thus the males are infertile. Females are also affected during the fetal development of the germ cells, and most oogonia die as they are entering meiosis. However, sometimes a mature follicle is present in the adult, and, rarely, confirmed foalings have been reported in both mules and hinnies.

**Congenital abnormalities are abnormalities that are present at birth.** They may be caused by genetic factors or some other agent. Teratogens are an agent that can induce abnormalities in a developing conceptus. Teratogenic agents may not kill the developing conceptus, but many of the abnormalities they induce are incompatible with life. Teratogens have their major effect during the embryonic stages. A teratogen may be a drug, hormone, chemical, gamma irradiation, trace element, variations of temperature, or an infectious agent (particularly viruses). For example, in the pig, swine fever (hog cholera) virus will produce neurological abnormalities such as demyelination, cerebellar and spinal hypoplasia, hydrocephalus, and arthrogryposis. In the dog, some common pharmacological agents such as corticosteroids and griseofulvin are known teratogens, and care must be exercised in their use in pregnant bitches. In the cat, the panleucopenia virus will cause teratogenic effects in pregnant queens. Congenital abnormalities may cause obstetrical problems. For example, *perosomus elumbis*, which occurs in ruminants and swine, is characterised by hypoplasia or aplasia of the spinal cord which ends in the thoracic region. The regions of the body, including the hind limbs, which are normally supplied by the lumbar and sacral nerves, exhibit muscular atrophy, and joint movement does not develop. The rigidity of the posterior limbs may then cause dystocia. *Schistosoma reflexus*, another abnormality common in ruminants and swine, has as the main defect acute angulation of the vertebral column such that the tail lies close to the head. The chest and abdominal cavities are incomplete ventrally so that the viscera are exposed. Again such cases may cause dystocia. Double monsters, which are found in a number of species, will present as absolute fetal oversize. Other examples of causes of fetal oversize are hydrocephalus and accessory limbs. Some of the congenital anomalies that are of importance in veterinary obstetrics have a genetic cause. For example, achondroplasia (dwalf calves) and amputates (otter calves) in Friesians, double muscling and arthrogryposis in the Charolais, and oedematous calves in the Ayrshire breed.

Following early embryonic death the embryonic tissues are usually resorbed, and the animal returns to oestrus if there is no other conceptus in the uterus. If death occurs before there has been maternal recognition of pregnancy the estrous cycle is not prolonged. If it occurs after recognition has taken place, the estrous cycle will be prolonged. If death of the embryo is due to an infection then, even although the embryonic material may be absorbed, a pyometra may follow. In cattle this condition is characterized by persistence of the corpus luteum, closed cervix and pus accumulation in the uterine body and horns. It is a particular characteristic of infection with *Tritrichomonas fetus*.

**DROPSY OF THE FETAL MEMBRANES AND FETUS:**
Three dropsical conditions of the conceptus may be seen in veterinary obstetrics: oedema of the placenta, dropsy of the fetal sacs and dropsy of the fetus. They may occur separately or in combination.

**Oedema of the placenta:**
This frequently accompanies a placentitis: for example, *Brucella abortus* infection in cattle. It does not cause dystocia but is frequently associated with abortion or stillbirth.

**Dropsy of the fetal sacs**

Both the amniotic and allantoic sacs can contain excessive quantities of fetal fluid. When this occurs it is referred to as hydramnios or hydrallantois, depending on which sac is involved. Hydramnios is much more common than hydrallantois, although the latter is always seen in association with specific fetal abnormalities such as the ‘bulldog’ calf in the Dexter. A few cases have been recorded in sheep, associated with either twins or triplets, in which the excess of fluid – amounting to about 18.5 litres – was in the amniotic sac. It has also been reported in the dog involving all fetuses in a litter. Apart from the hereditary cases of hydramnios which accompany the Dexter ‘bulldog’ calf, and which may occur as early as the third or fourth month, most instances of dropsy of the fetal sacs of cattle are seen in the last 3 months of gestation. The cause is not known. Histologically, there was a noninfectious degeneration and necrosis of the endometrium and, as already observed, the fetus was undersized. Normally, in cattle, there is a markedly accelerated production of allantoic fluid at 6–7 months of gestation, and it is suggested that, where placental dysfunction exists, this increase may become uncontrolled and lead to massive accumulation. It is also frequently associated with twins. All cases of hydrallantois are progressive, but they vary in time of clinical onset (within the last 3 months of pregnancy) and in their rate of progression. The essential symptom is distension of the abdomen by the excess of fetal fluid. The later in gestation the condition occurs, the more likely it is that the cow will survive to term, whereas if the abdomen is obviously distended at 6 or 7 months, the cow will become extremely ill long before term. The volume of allantoic fluid varies up to 273 litres, and such large amounts impose a serious strain on the cow and greatly hamper respiration and reduce appetite. There is gradual loss of condition, eventually causing recumbency and death. Occasionally, the animal becomes relieved by aborting. The less severely affected reach term in poor condition and, because of uterine inertia (often accompanied by incomplete dilation of the cervix), frequently require help at parturition.

The diagnosis of bovine hydrallantois is based on the easily appreciable fluid distension of the abdomen, with its associated symptoms, in the last third of pregnancy. Confirmation may be obtained by the rectal palpation of the markedly swollen uterus and by the failure to palpate the fetus either per rectum or externally. The treatment of hydrallantois calls for a realistic approach and a nicety of judgment. Cases that have become recumbent should be slaughtered. Where the animal is near term, a one- or two-stage caesarean operation is indicated. With both methods it is imperative that the fluid is allowed to escape slowly, so as to prevent the occurrence of hypovolaemic shock associated with splanchnic pooling of blood. Since hydrallantois is frequently seen in twin pregnancies in cows, it is particularly important to search the grossly distended uterus for the second calf. Cases of hydrallantois which calve, or are delivered by caesarian operation, frequently retain the placenta and, owing to tardy uterine involution, often develop metritis. This may lead to a protracted convalescence and delayed conception. By using a synthetic
corticosteroid (dexamethasone or flumethasone) in conjunction with oxytocin, improved therapy for hydrallantois. About 4 or 5 days after an injection of 20 mg of dexamethasone or 5–10 mg of flumethasone the cervix relaxes and the cow is given oxytocin by means of an intravenous drip for 30 minutes. Of 20 cows so treated, 17 recovered.

**Dropsy of the fetus**

There are several types of fetal dropsy, and those of obstetric importance are hydrocephalus, ascites and anasarca.

**Hydrocephalus**

Hydrocephalus involves a swelling of the cranium due to an accumulation of fluid which may be in the ventricular system or between the brain and the dura. It affects all species of animals and is seen most commonly by veterinary obstetricians in pigs, puppies and calves. In the more severe forms of hydrocephalus there is marked thinning of the cranial bones. This facilitates trocarisation and compression of the skull so as to allow vaginal delivery. Where this cannot be done, the dome of the cranium may be sawn off with fetotomy wire or a chain saw. If the fetus is decapitated there is still the difficulty of delivering the head. Caesarean section may be performed, but there is no merit in obtaining a live hydrocephalic calf; however, this operation, may be necessary in severe cases affecting pigs and dogs, and in cattle when the calf is presented posteriorly or when hydrocephalus is accompanied by ankylosis of the limb joints.

**Fetal ascites**

Dropsy of the peritoneum is a common accompaniment of infectious disease of the fetus and of developmental defects, such as achondroplasia. Occasionally, it occurs as the only defect. Aborted fetuses are often hydrocephalic; when the fetus is full-term, ascites may cause dystocia. This can usually be relieved by incising the fetal abdomen with a fetotomy knife.

**Fetal anasarca**

The affected fetus is usually carried to term, and concern is caused by the lack of progress in second-stage labour. This is due to the great increase in fetal volume caused by the excess of fluid in the subcutaneous tissues, particularly of the head and hind limbs. In the case of the head, there is so much swelling that the normal features are masked and the resultant appearance is quite grotesque. It is an interesting point that an undue proportion of these anasarcous fetuses are presented posteriorly, in which case the enormous swelling of the presenting limbs is very conspicuous. There is frequently an excess of fluid in the peritoneal and pleural cavities with dilatation of the umbilical and inguinal rings as well as hydrocoele. The substance of the fetal membranes is also oedematous and occasionally there is a degree of hydrallantois.

**Superfecundation**

Superfecundation is the condition in which offspring from two sires are conceived contemporaneously. Owing to the number of ova shed and their longevity, as well as to the length of oestrus and the promiscuous mating behaviour of the species, superfecundation is most likely in the bitch. The phenomenon is suspected when mating to two dogs of different breeds is known to have occurred, and the suspicion is heightened when the litter shows marked dual variation in color pattern, conformation and size. Superfecundation has been reported when a mare gave birth to twin horse and mule foals, and when a Friesian cow delivered twin Friesian and Hereford calves.

**Superfetation**

Superfetation is the condition that arises when an animal already pregnant mates, ovulates and conceives a second fetus or second litter. It is not uncommon for a cow
to be mated when pregnant, but no evidence is available that ovulation occurs in a cow carrying a live fetus. Ovulation does occur in pregnant mares, and in this species superfetation is theoretically possible. Superfetation is suspected when fetuses of very different size are born together or when two fetuses, or two litters, are born at widely separated times. Apparently authentic cases have been described in which two normally mature fetuses, or litters, have been delivered at times corresponding in gestation length to two widely separated and observed matings.

Prolapse of the vagina and cervix (CVP):

1-Sheep

The disorder is normally easily recognized, although sometimes the prolapsed organ can be confused with the allantochorion as it protrudes from the vulva before it ruptures. The severity of the disorder varies, and a number of different classifications have been used.

- Stage 1. In which the vaginal mucosa protrudes from the vulva when the ewe is recumbent, but disappears when she stands.
- Stage 2, in which the protruding vaginal mucosa remains visible even when the ewe stands; the cervix is not visible.
- Stage 3. In which the vagina protrudes, and the cervix is visible.

Other systems of classification have been used which also take into account the duration of the prolapse, its size and the other organs contained within the prolapsed organ; they use the terms mild, moderate and severe. The bladder is most frequently involved as it becomes reflected to occupy the vesicogenital peritoneal pouch. This can be followed by complete or partial constriction of the urethra causing urinary retention; the uterine horns and intestines can also be involved. Real-time ultrasonography can be used to diagnose the contents of the prolapse.

Causes and pathogenesis:

- Hormonal excesses and imbalances
- Hypocalcaemia
- large fetal load (twins or triplets)
- fat condition
- thin condition
- inadequate exercise
- short tail docking
- bulky food (root crops)
- excess dietary fibre
- dietary oestrogens and their precursors
- sloping terrain
- vaginal irritation
- previous dystocia
- inherited predisposition.

Predisposing factors:

- The vaginal wall must be in a state where it can be readily everted, and the vaginal lumen must be large.
- The vulva and vestibular wall must be relaxed.
- There must be a force which can displace the vaginal wall, causing it to become everted.

Clinical signs and progression of the disease:

The clinical signs are obvious; the only possible confusion might be the protruding allantochorion. Prolapse occurs most frequently in the last 2–3 weeks of gestation. The only distinction that needs to be made is the severity. In sheep a severe prolapse
with heavy straining is not well tolerated, and fatalities from shock, exhaustion and anaerobic infection are common. Abortion, or premature delivery, often of a dead fetus, may be followed by a rapid maternal recovery.

Treatment:
Treatment of ewes with CVP is often done without any consideration for the welfare of the animal. It is relatively easy for veterinarians to reduce pain and discomfort during replacement by using caudal epidural anesthesia. In sheep, the perineal wool, or string fastened to it, may be tied across the vulva; large safety pins have sometimes been used. The early replacement and retention of the prolapse is very important to prevent trauma and to ensure that the ewe maintains pregnancy to term.

2-CATTLE

Causes and pathogenesis
The exact cause of the disorder has not been ascertained but several factors are generally believed to play a part. The anatomical anchorage of the genital tract is less efficient than in other animals. An excessive deposition of fat in the perivaginal connective tissue and ligamentous relaxation may increase the mobility of the vagina. Both these effects might be due to a state of endocrine imbalance, in which estrogenic hormones predominate; the administration of stilboestrol has been shown to soften the suspensory ligaments of the genital tract. Where estrogenic substances are present in inordinate amounts in the diet, as in subterranean clover pastures of Western Australia, or in mouldy maize and barley which are considered to have a high oestrogen content, this can result in a high incidence of prolapse. When heifers are fed these in their diet they may show vulvovaginitis with oedema of the vulva, relaxation of the pelvic ligaments, tenesmus and vaginal prolapse. Predisposition to CVP is inherited, as shown by its greater frequency of occurrence in beef cattle. Mechanical factors, such as the increasing intra-abdominal pressure of late pregnancy and gravity, acting through the medium of a sloping byre floor when cattle are tethered, are considered significant. Postparturient prolapse of the vagina of cattle is usually due to severe straining in response to vaginal trauma, or infection, following a serious dystocia. Vaginal contusion at parturition, followed by Fusobacterium necrophorum infection, exerts a high degree of irritation with frequent exhausting expulsive efforts.

Clinical signs and progression of the disease:
Initially, the lesion involves a protrusion of the mucous membrane – more particularly of the floor – of that part of the vagina which lies just cranial to the urethral opening. In severe cases the whole of the anterior vagina and cervix may protrude. The further from parturition that the disease begins, the more serious it is likely to become because advancing pregnancy tends to accentuate the condition. In cattle most cases are seen in the last 2 months of gestation. In the mildest cases the lesion appears only when the cow is recumbent; when the animal rises the prolapse recedes. The tendency is, however, to a progressive degree of prolapse and, in time, a larger bulk protrudes and does not disappear in the standing position. Now the dependent tissue, with its circulation impeded, is prone to injury and infection. The resultant irritation causes expulsive straining efforts. This increases the degree of prolapse, and a vicious circle is established. Eventually the whole of the vagina, cervix and even the rectum may become everted. Thrombosis, ulceration and necrosis of the prolapsed organ, accompanied by toxaemia and severe straining, lead to anorexia, rapid deterioration in bodily condition and occasionally death.

Treatment
If prompt attention is given, simple measures often succeed. The aim is to arrest the process by early replacement and retention of the prolapsed portion. Caudal epidural anesthesia is indicated both to obviate straining and to desensitise the perineum for suturing. The everted mass is washed clean using plain water or a mild non-irritant antiseptic and replaced gently with the palms of the hand, being careful not to cause trauma to the inflamed and sometimes fragile tissue. It is retained by tape or stout nylon sutures which cross the vulva and are inserted in the perineal skin. Quill sutures tied over rubber tubing are best. In cases where the vagina has suffered little damage and especially where parturition is imminent, such measures are usually sufficient, particularly when, as is possible with dairy cows, the patient can be stalled on a forward slope. Straining may be controlled by caudal epidural anesthesia, and although xylazine will prolong its effect, it is not practicable to provide continuous anesthesia by this means. Perineural injection of the pudic nerves had the same effect, and the same disadvantage. For cows showing recurrent prolapse and which are remote from parturition, and also for postpartum cases. Method of almost complete surgical occlusion of the vulva by a technique which is really an extension of Caslick’s plastic operation for preventing vaginal aspiration. Under caudal epidural or local infiltration anesthesia, strips of mucous membrane, 1.2 cm wide, are dissected from the upper three-fourths of each vulval lip. The denuded areas are then approximated by means of fine nylon sutures, and a few mattress sutures of tape or stout nylon are deep placed across the vulva to protect the coapted lips from the effects of straining. First-intention healing should occur, and the suture line must be incised when parturition is imminent. The object of the operation, which should not be performed later than 3–4 weeks from term, is to excise the protruding mucosa – which forms the bulk of the everted mass – and then approximate the cut edges. Proximal and distal encircling incisions through the mucous membrane are made near the urethral opening and the cervix respectively, and the intervening mucosa, in the form of a crescent, is removed by blunt dissection through the oedematous submucosa. In order to control hemorrhage and to facilitate suturing, it is best to perform the circumferential dissections in separate segments; as the resection of each segment is completed, so the cut edges are coapted with continuous catgut or other absorbable sutures. The operation is performed under posterior epidural anesthesia.

**Effect of drugs used during pregnancy.**

Important physiological changes occur during pregnancy that may alter the processes of drug absorption, distribution, and elimination. Changes occur in the cardiovascular, pulmonary, renal, and gastro-intestinal systems, and in body water compartments. The placenta, amniotic fluid, and fetus constitute additional distribution compartments for drugs. Drug exposure of offspring during pregnancy is determined by transplacental transfer. The rate and degree of transplacental transfer is influenced by the same principles and factors that affect transfer across other cellular barriers. These are: the concentration of free drug on each side of the barrier, the degree of ionisation, and the lipid solubility of the unionised drug. As a general rule, if a drug can be absorbed from the gut it will
usually cross the placenta and enter the fetus. The fetus is susceptible to damage during implantation, when embryonic death is the outcome; during the embryonic and fetogenic stages when teratogenesis may result, and at birth when CNS, cardiovascular and respiratory depression are the most serious effects. Some drugs may cause abortion, congenital malformations or neonatal disease if administered during pregnancy. Drugs that are known to cause teratogenesis in animals include some benzimidazoles such as albendazole and oxfendazole (particularly at high doses), corticosteroids, griseofulvin, ketoconazole, and methotrexate. Drugs that may affect the fetus or neonate include opioids and barbiturates, which may alter respiration. Diethylstilbestrol administered for misalliance, may cause aplastic anaemia in offspring. Chlorpropamide and tolbutamide may cause hypoglycaemia. Salicylates (including aspirin) are teratogenic and prolonged use may also increase the risk of haemorrhage. Tetracyclines may cause dental discoloration and malformation in the offspring. Corticosteroids may cause teratogenesis and also affect skeletal calcification. Steroid hormones including androgens, anabolic steroids, and progestogens are teratogenic and may affect the sexual development of the offspring. Drugs may induce abortion or premature parturition and these are discussed below. This does not mean that the use of drugs is contra-indicated in pregnant animals, but drug selection and manufacturer’s warnings on the data sheets and package leaflets must be considered. The need for therapy of the dam must be weighed against the generally uncertain risk to the fetus. It is important that the balance of risks is fully discussed with the client. Sometimes administration during a certain period of pregnancy is not recommended. In many cases, safety has not been established and limited data are available on the consequences of administering drugs to the dam during pregnancy; manufacturer’s information on the effect of drugs in laboratory animals may be helpful when assessing drug safety in other species. The pharmacological class of drug, the physicochemical properties that influence its passage by passive non-ionic diffusion across the placental barrier, and the mechanisms of elimination of the drug must also be taken into account. Modification in dosage, if required, should be based on changes in pharmacokinetic parameters, such as bioavailability, systemic clearance, apparent volume of distribution, and half-life. It must be remembered that the dam’s cardiovascular, respiratory, renal and metabolic physiology are changing throughout pregnancy, as are those of the fetus. Unfortunately, too few studies of the absorption, distribution, and disposition kinetics of drugs have been performed in pregnant animals to allow even general recommendations to be made on dosage modifications. Effect of drugs used at parturition.

Drugs may cause pregnancy termination or premature parturition. Abortion may be induced by corticosteroids, cabergoline, some prostaglandins, and alpha2-adrenoceptor stimulants such as xylazine. Prostaglandins are used therapeutically to terminate early pregnancy in cattle, and to induce parturition in cattle and pigs. In dogs, the progesterone receptor antagonist aglepristone is used for the prevention of implantation and the termination of pregnancy before day 45. When drugs are used to induce early parturition, the length of gestation should be calculated to minimise the risk of nonviable offspring. Drugs may also prolong normal delivery. Clenbuterol is used as a bronchodilator and also to reduce uterine motility. When used to treat a respiratory condition, therapy should be discontinued before the expected date of parturition. Progestogens may delay parturition. NSAIDs may delay or prolong parturition, and may cause premature closure of the fetus’s ductus arteriosus.
<table>
<thead>
<tr>
<th>Drugs to be avoided or used with caution in pregnant animals</th>
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<tr>
<td>These drugs can present hazards to certain operators such as women of child-bearing age and pregnant women, as well as the patient</td>
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<td>This list is not comprehensive; absence from the table does not imply safety</td>
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<tr>
<td>Aglepristine</td>
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<td>Amitraz</td>
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<td>Atipamezole</td>
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<td>Barbiturates (including phenobarbital)</td>
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<td>Benazepril</td>
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<td>Beta-adrenoceptor blocking drugs</td>
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<td>Some benzimidazoles</td>
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<td>Bromocriptine</td>
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<td>Buprenorphine</td>
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<td>Clenbuterol hydrochloride</td>
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<td>Corticosteroids</td>
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<td>Cyromazine</td>
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It is essential for the veterinarian to be perfectly familiar with the normal course of parturition in domestic species in order to be able to differentiate between physiological and pathological birth. The appropriate intervention at the correct time can increase the likelihood of a successful outcome, by ensuring that both mother and offspring survive.

The fetus is responsible for the initiation of birth in the domestic animal species. The endocrine pathways involved vary to an extent between species; they have not been fully elucidated in some species. A rise in the production of fetal cortisol occurs as a result of changes in and maturation of the hypothalamic–pituitary–adrenal axis of the fetus. This is thought to be caused by fetal stress, which develops as the placenta is less able to supply the needs of the growing and demanding fetus.

The endocrine events that precede birth can be summarized as follows:

1. increased production of corticotropin-releasing hormone (CRH) by the fetal brain
2. increased production of adrenocorticotropic hormone (ACTH) by the fetal anterior pituitary gland
3. increased production of cortisol by the fetal adrenal glands
4. conversion of placental progesterone to estrogen
5. estrogen stimulates production of prostaglandin F2α (PGF2α) by the myometrium and also induces some cervical relaxation
6. PGF2α induces myometrial contraction, which increases intrauterine pressure and moves the fetus towards the cervix, causing further cervical dilation
7. oxytocin is released by the maternal posterior pituitary gland as the cervix is dilated by the fetus (Ferguson’s reflex)
8. oxytocin induces further myometrial contractions.

For ease of description, parturition is divided into three stages. There is no clear demarcation between the stages, which normally merge with each other to become a continuous process. The length of each stage is quite variable. Before parturition a number of other preparatory changes such as mammary development and relaxation of the pelvic ligaments occur. The timing of these preparatory changes varies between individual animals, making them rather unreliable indicators of approaching birth.

The main physiological events of the three stages of labor are listed below:

- **First stage:**
  - relaxation and dilation of cervix
  - fetus adopts birth posture
  - uterine contraction commences
  - chorionallantois enters vagina

- **Second stage:**
  - uterine contraction continues
  - fetus enters birth canal
  - abdominal contraction commences
  - amnion enters vagina
  - fetus is expelled

- **Third stage:**
  - placental circulation lost
  - placental dehiscence and separation occurs
  - uterine and abdominal contractions continue
  - placenta is expelled.

- **Presentation:** the relationship between the long axis of the fetus and the long axis of the maternal birth canal. Thus presentation can be longitudinal (anterior or posterior), transverse, or (rarely) vertical.

- **Position:** that surface of the maternal birth canal to which the fetal vertebral column is applied. Thus position can be dorsal, ventral, or lateral (right or left).

- **Posture:** the disposition of the head and limbs of the fetus.
**Initiation of parturition:**

The uterine musculature is the key component of labour, and the essential physiological change between gestation and birth is a liberation of the contractile potential of the myometrium; the factors involved in this transformation are neural, humoral and mechanical. Of the humoral factors, the most important is the reversal of those mechanisms which are necessary for the maintenance of pregnancy, in particular the removal of the progesterone block, which ensures that, during this phase of the animal’s reproductive life, the myometrium is largely quiescent.

Parturition in the ewe occurs as result of activation of the fetal hypothalamus–pituitary–adrenal (HPA) axis; the areas of the hypothalamus involved in this process are the paraventricular nuclei. The fetal HPA axis is similar to the adult HPA axis, except that the fetal brain is still developing in late gestation and the former communicates with the latter via the placenta. There is still uncertainty about the mechanisms responsible for the activation of the fetal hypothalamus. A number of theories have been proposed. These are:

- maturation of the fetal hypothalamus which might result in the development of critical synapses in the paraventricular nucleus, allowing an increase in fetal neuroendocrine function
- ability of the hypothalamus to respond to the effects of placental hormones
- fetal stressors such as hypoxia, hypercapnia, changes in blood pressure and blood glucose. It is also postulated that placentally-derived hormones such as oestrogens, progesterone, PGE2 or corticotrophin-releasing factor (CRF) may also act on the hypothalamus. During the last 20–25 days of gestation, there is a dramatic rise in fetal cortisol concentrations, which reach a peak 2–3 days before birth, thereafter declining 7–10 days postpartum. The source of the increase in fetal cortisol is the fetal adrenal, which is due to both an increase in the size of the organ in relation to total body weight, and an increase in its sensitivity to adrenocorticotrophic hormone (ACTH) as a result of accelerated processing of ACTH from pro-opiomelanocortin (POMC); maternal cortisol concentrations only rise around the time of parturition. At the same time, the binding capacity of the fetal plasma increases, thus reducing the amount of free cortisol in the fetal circulation and thereby reducing the negative feedback effect on the secretion of ACTH by the fetal pituitary. In sheep fetal pituitaries, the ‘fetal’ corticotrophs are replaced by smaller stellate cells, the so-called ‘adult’ corticotrophs, around 125 days of gestation, which might reflect an increased potential for ACTH secretion. There is an increase in corticotrophin-releasing hormone (CRH) in the fetal hypothalamus during the last 10 days of gestation and, in addition, it has been suggested that the placenta of the sheep can also secrete CRH. Endogenous opioids may also play a role in stimulating ACTH secretion via their effect upon the fetal hypothalamus rather than the pituitary. It has been shown experimentally that when exogenous opioids are infused into the fetal lamb, there is an increase in ACTH which can be abolished by the administration of the opioid antagonist naloxone. POMC peptides and arginine
vasopressin may also be involved in ACTH secretion since both increase towards the end of gestation. The fetal adrenal becomes more responsive to ACTH stimulation with advancing age. Insulin-like growth factors (IGFs) may have an autocrine and/or paracrine role in regulating ovine fetal adrenal function. Fetal growth hormone, which is elevated from 50–70 days of gestation and then falls until 100 days, before increasing to term, may also modify the response of the fetal adrenal to ACTH. The rise in fetal cortisol stimulates the conversion of placentally-derived progesterone to oestrogen by activating the placental enzyme 17α-hydroxylase; this hydroxylates progesterone via androstenedione to oestrogen. The consequences of the rise in oestrogens in the peripheral circulation are threefold. Firstly, oestrogens have a direct effect upon the myometrium, increasing its responsiveness to oxytocin; secondly, they produce softening of the cervix by altering the structure of collagen fibres; thirdly, they act upon the cotyledon–caruncle complex to stimulate the production and release of prostaglandin F2α (PGF2α). The latter change is induced by the activation of the
enzyme phospholipase A2 stimulated by the decline in progesterone and rise in oestrogen. This enzyme stimulates the release of arachidonic acid from phospholipids, so that under the influence of the enzyme prostaglandin synthetase, PGF2α is formed. Prostaglandins play a key role in initiating parturition; because of their molecular structure they are soluble in fat and water so that they readily pass from cell to cell via cell membranes or between cells in the extracellular fluid. Two prostaglandins are produced by the uterus – PGF2α in the endometrium and, during expulsion of the fetus in the myometrium, prostacyclin (PGI2). Prostaglandins have a wide range of actions; they cause smooth muscle contraction, luteolysis, and the softening of cervical collagen as well as stimulating smooth muscle cells to develop special areas of contact called gap junctions, thereby allowing the passage of electrical pulses and ensuring coordinated contractions. PGF2α is considered to be the intrinsic stimulating factor of smooth muscle cells, and thus its release is important in initiating myometrial contractions. The effect of these contractions is to force the fetal lamb towards the cervix and vagina where it will stimulate sensory receptors and initiate Ferguson’s reflex, with the release of large amounts of oxytocin from the posterior pituitary. Oxytocin will stimulate further myometrial contractions and the release of PGF2α from the myometrium. Hence both these hormones, together with uterine contraction, seem to work as a positive feedback system of increasing magnitude, thus stimulating further uterine contractions and consequent expulsion of the fetus. Maturation of the fetal lamb’s lungs, especially the production of alveolar surfactant, is stimulated by cortisol, as are many other changes in fetal function and structure that enable the lamb to survive after birth.

**Goat:**
In this species, the CLs provide the essential source of progesterone necessary for the maintenance of gestation, since ovariectomy or extirpation of the CLs will terminate pregnancy. Placental 17α-hydroxylase, which is stimulated by the rise in fetal cortisol, diverts the synthesis of progesterone by the CLs into oestrogen. The change in the oestrogen:progesterone ratio stimulates PGF2α synthesis as in the ewe, resulting in luteolysis with a further decline in progesterone. Progesterone disappears from the circulation before parturition can occur. The endocrine changes are very similar to those in the sheep and cow.

**Mare:**
The mechanisms responsible for the initiation of parturition are not as well understood as those of the previous four species; there is less circumstantial and experimental evidence. However, it is likely that the fetal foal is responsible for the initial trigger mechanism, since the fetal adrenal undergoes rapid hypertrophy immediately before parturition and fetal plasma cortisol concentrations have been shown to increase nearly 10-fold during the last 8 days before foaling. Since it has been shown that in the peripheral circulation of the newborn foal, β-endorphin concentrations are raised, it has been suggested that they may be involved in triggering parturition. However, it is also possible that they are produced in response to the act of parturition. The main difference from the ewe relates to the endocrine changes that occur in the maternal circulation. Progestogens (progesterone and progestins) remain low from the middle of pregnancy until the last 2–3 months of gestation; they then increase, especially during the last 20 days, to reach a peak about 48 hours before parturition. They then decrease rapidly to low levels at the time of parturition. Plasma oestrogen concentrations decline during the last 100 days of gestation, rather than increase as in other species, reaching relatively low levels at parturition, although this is largely a reflection of the decline in oestrone and the species-specific oestrogens, equilin and
equilenin, since concentrations of oestradiol–17β remain fairly constant. Parturition constitutes transport of the fetus and its associated membranes from the maternal to the external environment. The fetal hypothalamic-pituitary-adrenal axis initiates the process of fetal maturation and the cascade of endocrine and neural events that lead to parturition in the mare; however, the specific physiologic processes are somewhat different in the mare than other animal species. CRF stimulates the release of ACTH from the fetal pituitary, and ACTH, in turn, stimulates secretion of cortisol by the adrenal glands. Elevations in fetal cortisol (fetal LH may be involved as well) appear to modulate uterofetoplacental steroid metabolism. Progestagens decrease precipitously approximately 24 hours prior to parturition, and, although total estrogen concentrations decrease in the maternal circulation during late gestation, specific estrogens are thought to be locally active in the uteroplacental tissues during the initiation of equine parturition. Following this change in the relative influences of progestagenic and estrogenic hormones on uteroplacental tissues, several events occur that prepare the uterus for parturition. The cervix softens, most likely facilitated by relaxin and cervical production of PGE2. Oxytocin receptors in the myometrium increase in number, and PGF is synthesized within the uterus. Blood flow to the gravid uterus and placenta increases, allowing for adequate fetal oxygenation and nourishment, as well as a means of supplying hormone, sources of energy, and oxygenated blood to the uterus. Neural signals caused by fetal movements and myometrial contractions are involved in a complex interaction with slightly elevated basal levels of oxytocin and increased secretion of PGF to bring about the first stage of labor. There is a short period of uterine quiescence during the first stage of labor, most likely due to a surge in relaxin, which immediately precedes a rapid increase in oxytocin and PGF secretion, which leads to rupture of the allantochorionic membrane and commencement of the second stage of labor. Strong myometrial contractions result and the foal is delivered in a very short time (5–45 minutes). This myometrial activity declines after foaling but is maintained at a level sufficient to ensure expulsion of the fetal membranes. The importance of the fetal hypothalamic-pituitary-adrenal axis, as well as other endocrine and neurologic pathways, in equine parturition is evident from the hormone profiles of foals, as well as mares, in a number of disease syndromes. Blood cortisol levels are decreased in premature, dysmature, and overmature individuals as compared to normal foals. Decreased triiodothyronine levels in premature, dysmature, and overmature equine neonates suggest that fetal thyroid hormones may also play a role in fetal maturation and the initiation of the foaling process. Maternal levels of prolactin, relaxin, and progestagens are all decreased in cases of “fescue toxicosis” or ergot-associated prolonged gestation, and treatment with D2-dopamine receptor antagonists, unlike administration of rauwolfian alkaloids (e.g., reserpine), results in reversal of these endocrine trends, along with the onset of apparently normal parturitions. The mare has more control over the first stage of labor than do other species, and external stimuli (such as lights and noise) can suppress oxytocin secretion and delay foaling. Parturition can be induced in the mare using oxytocin or a combination of prostaglandin and oxytocin. Certain criteria (duration of gestation, quality of mammary secretion, and cervical relaxation) must be met to ensure that foaling induction is safe for both the mare and foal. Equine parturition is a very rapid and powerful event and maternal and fetal survival depend on adequate supervision and prompt and appropriate intervention when indicated.
The role of relaxin:
Relaxin, a polypeptide hormone, was shown to be responsible for causing relaxation of the pubic symphysis of guinea pigs. The most potent sources of this hormone are the CLs of the pregnant sow; however, it is now known to be produced by a number of other tissues such that it has a wide diversity of chemical structure and physiological effects between species. In the pig, as well as from the CLs of the pregnant sow, it is also produced by preovulatory follicles. In the cow, the CL appears to be the main source of the hormone, with values increasing just before calving; however, because a reliable assay is not available in this species, some of the results are equivocal. There is conflicting evidence in the ewe concerning the secretion of the hormone as well as its likely source of production. In the horse, dog and cat, the main or sole source of the hormone is the placenta. In the mare, concentrations start to rise from about 80 days of gestation, although there is considerable breed variation. In the bitch, relaxin increases from about 4 weeks of gestation, and remains elevated until term, whereas in the cat there is a sudden rise from 23 days of gestation with a peak at 36 days and a dramatic decline just before parturition. In the sow, relaxin stimulates the growth of the cervix during late pregnancy as well as causing relaxation before parturition. The latter changes, which are also influenced by the oestrogen: progesterone ratio, involve changes at a biochemical level, by influencing the glycosaminoglycans: collagen ratio and histological structure. Relaxin plays an important role in cervical relaxation at term. Studies have shown that when highly purified porcine relaxin was placed directly on the external os of the cervix at 276–278 days of gestation, cervical relaxation occurred 8–12 hours later. Similar results have been obtained when parturition has been induced with dexamethasone. The reports on the effect of porcine relaxin on the cervix of the sheep are equivocal. Recent work has shown that a relaxin-like mRNA cannot encode a functional relaxin molecule, which suggests that sheep may not produce relaxin and thus, in this species, cervical relaxation may not be relaxin-dependent. Relaxin also exerts an influence on myometrial activity, with several studies reported in domestic species, in particular the pig. In general, relaxin reduces both the frequency and amplitude of uterine contractions, particularly the former. It appears to act in concert with progesterone, oestrogens, oxytocin and prostaglandins. Thus in the sow, although the progesterone concentrations have fallen significantly 10–24 hours before farrowing, with the removal of the progesterone block, myometrial activity is low. At this time, relaxin concentrations increase significantly. Furthermore, in sows there is a relationship between relaxin concentrations and the duration of farrowing.

Fetal maturation:
Examples of some of the changes that occur during Fetal maturation are: physical, such as closure of the ductus arteriosus and foramen ovale; and functional, such as the development of glucose homeostatic mechanisms, changes in the structure of haemoglobin from the fetal to the adult form. If premature induction with the exogenous hormones bypasses some of the endocrine changes that normally occur, the newborn may be unprepared. This has been demonstrated when goat kids, which were born following the injection of PGF2α, were compared with those which were born after induction with ACTH. The link between parturition and maturation of the fetus appears to be related to the adrenal cortex and the prepartum surge of fetal cortisol. During its intrauterine life the fetus is in a thermally neutral environment, but at birth it has to be able to maintain its own body temperature. The mechanisms which enable this are the accumulation of brown fat and glycogen in late gestation and maturation of the thyroid gland. The latter process occurs as a result of the prepartum
rise in fetal cortisol, which stimulates the monodeiodination of the thyroid hormones, thus enhancing their biological activity. The maintenance of glucose homeostasis immediately after birth, when the newborn loses its placental source of glucose, is dependent on adequate stores of liver glycogen. There is strong evidence that in sheep the stimulus for the accumulation of glycogen stores in late gestation is the rise in fetal cortisol. The glycogen stores are just sufficient to provide energy before sources of glucose become available from food. A similar stimulus to the production of insulin by the pancreas has also been attributed to the effect of elevated fetal cortisol, which enables the newborn to respond quickly to maintain glucose homeostasis. The fetal adrenal medulla also shows evidence of maturational changes in that its ability to produce catecholamines, especially adrenaline, is increased in response to asphyxia. There is some evidence that adrenaline, together with fetal ACTH and cortisol, stimulates lung maturation, thus enabling normal respiratory function to occur.

**Premature induction of parturition:**
Although it is usually possible to predict approximately when parturition will occur in domestic species there are obvious advantages in being able to predetermine when the event will occur. Many of the methods that are used have originated from studies of the endocrine changes responsible for the initiation of normal parturition.

**Mare**
The indications for the premature induction of foaling are few, the main one being to ensure that it occurs in the presence of skilled assistance; then if dystocia occurs it is possible quickly to correct the difficulty so as to ensure survival of the foal and reduce the danger to the mare. There are also, on a few occasions, when, because of disease or illness in the mare, it may be advantageous for foaling to be induced. Intramuscular injection of oxytocin, either alone or without priming with stilboestrol dipropionate. If the cervix showed evidence of ‘ripening’, i.e. was soft on palpation and able to allow the insertion of one or two fingers in the external os, and the foal was in normal presentation, position and posture, oxytocin was given at a dose of 120 IU to mares between 360 and 600 kg live weight. Foaling occurred 15–60 minutes later. If the cervix was ‘unripe’, 30 mg of stilboestrol dipropionate in oil was given intramuscularly, followed by oxytocin 12–24 hours later, provided that the cervix had responded. A relationship between the dose of oxytocin and placental separation has been demonstrated, doses of less than 60 IU resulting in retention. It is important to know the precise gestational age since induction should not be attempted before 320 days; even then because of the wide variation in the gestation length in the mare, foal viability is poor. Dexamethasone, a quick-release synthetic corticosteroid, has been used successfully to induce foaling in ponies and large ‘saddle-type’ mares. A dose rate of 100 mg every day for 4 days resulted in parturition 6–7 days after the start of treatment in the latter type, whilst the ponies responded more rapidly. The regimen was started at 321 days of gestation, with satisfactory foal survival and subsequent growth rate. PGF2α have also been used to induce foaling. A single dose of PGF2α is not always effective; quite often it is necessary to use repeated injections of 1.5–2.5 mg every 12 hours. In some cases these prostaglandins can cause discomfort and can result in a high incidence of dystocia due to abnormalities in the position of the foal. It is also possible to induce foaling by the administration of progesterone; the interval from injection to effect is very similar to that following dexamethasone. It is possible that, as in other species, progesterone is metabolized by the adrenal or placenta to corticosteroid.

**Cow**
The indications for the induction of calving are as follows:
1-vancing the time of calving to coincide with the availability of suitable pasture for milk production.

2-suring that cows calve at a predetermined time when skilled assistance is available so that prompt attention can be given. This should reduce calf mortality and injury to the cow.

3- Reducing birth weight of the calf by shortening the length of gestation. During the last weeks of gestation the growth rate of the calf is rapid; in some of the exotic breeds, such as the Charolais, the live weight of the calf can increase by between 0.25 and 0.5 kg per day. Thus if the dam is immature, with a small pelvis, or pregnancy is prolonged beyond 280 days, as occurs in some exotic breeds, the calf may be too large to traverse the birth canal. Premature induction can thus reduce the likelihood of dystocia due to fetomaternal disproportion.

4- diseased or injured cows where the termination of pregnancy will alleviate the condition, or where a live calf can be obtained before slaughter, premature induction may be used. Cows suffering from hydrallantois will frequently respond.

*induction before 270 days will usually result in the birth of a small, weakly calf with poor prospects of survival it is important that the date of service or insemination is accurately known.*

ACTH has been used to induce calving, since it exerts its effect by stimulating endogenous corticosteroid production, it is best replaced by the direct administration of corticosteroids. A number of potent synthetic ones are available. There are three main categories; these are referred to as long-acting, medium-acting and short-acting, their classification being based upon the duration of the latent period (time interval from treatment to effect). Thus, when given at a normal therapeutic dose rate, the long-, medium and short-acting corticosteroids have latent periods of 11–18, 5–11 and 1–6 days, respectively. It is important to give large breeds of cows an adequate dose; in the case of betamethasone up to 35 mg is necessary in the Charolais. Corticosteroids are also immunosuppressive and thus they should not be given without broad-spectrum antibiotics if infection is present; the lungs and udder should be carefully examined beforehand. PGE1, PGE2 and PGF2α and analogues of the latter have been used. In the first reported use of prostaglandins; a minority of calvings were described as being associated with ‘explosive expulsions’, a 42% incidence of dystocia due to poor cervical dilation. However both PGF2α and the analogues have been successfully used from about 275 days of gestation with a latent period of 2–3 days. Good results have been obtained by using a combination of corticosteroid and prostaglandin. Beal et al. (1976) injected PGF2α if no effect had occurred 40 hours after treatment with dexamethasone. Day (1978) obtained good results using a prostaglandin analogue, cloprostenol, administered 8 or 12 days after pretreatment with dexamethasone trimethylacetate; all the cows calved within 72 hours. In a similar trial, involving 26 adult Friesian cows ranging in gestation from 237 to 270 days, 20 mg of dexamethasone phenylpropionate was given, and induced calving in 13 cows on average 5.6 days later. Those that failed to respond received 500 μg of cloprostenol after 10 days, and all calved within 3 days; all live born calves survived (Murray et al., 1982). In summary, for early induction (250–275 days of gestation) a long-acting corticosteroid is administered followed by a short-acting corticosteroid or PGF2α after 8 days if calving has not occurred; the latent period is about 48 hours. After 275 days, a medium acting corticosteroid, with either a short-acting corticosteroid or PGF2α after 8 days if the cow has failed to
calve, is used. After 282 days, PGF2α or short- or medium-acting corticosteroids are effective on their own.

There are, however, some disadvantages of premature induction of calving. It is not always effective. The birth weight of the calf is lower than it would have been at term, and thus the subsequent growth rate is reduced. There is also a high incidence of retained fetal membranes, up to 53% when ‘short-acting’ preparations are used. Milk yield is initially affected, with a delay in reaching peak lactation, although there appears to be very little influence on the overall yield. There is a reduction in the quality and quantity of colostral immunoglobulins, especially following the use of slow-release corticosteroid preparations, but it is unlikely that the calf will not acquire an adequate passive immunity.

Ewe

Parturition can be induced in the ewe by means of ACTH, corticosteroids and oestrogens. The indications for induction are limited since dystocia due to fetomaternal disproportion is not as common as in cows. However, a system which can guarantee that lambing will occur only during the hours of daylight when skilled assistance is available might reduce any problems due to dystocia and increase lamb survival rates. However, it is not possible to shorten gestation length appreciably without increasing lamb mortality.

As with other species, an accurately known gestational age is important. When corticosteroids such as dexamethasone, flumethasone and betamethasone are given by a single intramuscular injection within 5 days of term, normal parturition occurs in 2–3 days. Induction is also possible with two intramuscular injections of 1–2 mg of oestradiol benzoate 5–6 days before term or with a single injection of 15 mg of oestradiol benzoate 5 days before term.

Doe (nanny) goat

Parturition has been successfully induced with ACTH, corticosteroids, PGF2α and analogues, and oestrogens; however, lactation sometimes occurs prematurely.

Bitch and queen cat

Except for the induction of abortion using PGF2α, epostane and a prolactin inhibitor cabergoline, attempts to induce parturition in these species have been unsuccessful.
In polytocous species, the first stage of labor is followed by a series of second-stage fetal deliveries. These are followed by either a third stage after each second stage or the passage of placentas after the delivery of a group of or all the offspring.

FETAL PRESENTATION, POSITION, AND POSTURE

For ease and accuracy of description the terms presentation, position, and posture are used to indicate the orientation of the fetus in normal and abnormal birth. Their definitions are as follows:

- **Presentation**: the relationship between the long axis of the fetus and the long axis of the maternal birth canal. Thus presentation can be longitudinal (anterior or posterior), transverse, or (rarely) vertical.
- **Position**: that surface of the maternal birth canal to which the fetal vertebral column is applied. Thus position can be dorsal, ventral, or lateral (right or left).
- **Posture**: the disposition of the head and limbs of the fetus.

The main features of normal birth in each of the domestic species is now described.

NORMAL BIRTH IN THE COW

Gestation length is 283 days in Holstein–Friesian cattle; 290 days is normal in some Continental beef breeds.

Preparatory changes

The most important external changes are seen in the udder, vulva, and pelvic ligaments. Towards the end of pregnancy the udder becomes enlarged and tense. Colostrum is present in the teats and becomes thicker and yellow in color as birth approaches. Leakage of milk ('running milk') prior to calving can lead to loss of the thick colostrum, leaving only normal milk. This can result in serious loss of antibodies for the calf. In heifers, substantial subcutaneous edema can develop in front of and behind the udder. The edema normally disperses within a few days of calving.

As birth approaches, the vulva normally lengthens and might become slightly tumesced and edematous. In some animals, however, no vulval changes are seen. Clear vaginal mucus – believed to be the liquefying cervical seal and resembling the estral secretion – might be seen 24–48 hours before calving. Although body temperature drops before calving, the variation in timing and extent of the change make it an unreliable parameter.

Relaxation of the pelvic ligaments is seen in late pregnancy, becoming more pronounced as birth approaches. It is the most reliable sign of impending parturition in cattle. As a result of this, the cow's tail head might appear to be raised and the gluteal muscles sunken. These changes can be less obvious in fat cows but ligamentous relaxation can be detected internally in such animals by rectal examination. The muscular tone of the tail is reduced 24 hours before calving.

On rectal examination the fetal limbs or head are palpable in the maternal pelvis or immediately in front of it. Evidence of fetal life can be detected by spontaneous movement or by response to applying gentle pressure to the fetus. A uterus containing a very large, oversized fetus can slip down under the maternal rumen, where it is less easily palpated. Although some slight softening of the cervix can occur and be detected on vaginal examination in late pregnancy, true relaxation does not occur until the first stage of labor.

Many stockpersons are extremely good at predicting the prospective time of birth in their animals. Veterinary surgeons, aware of the unreliability of the prepartum physical changes, are advised to refrain from predicting the exact time of impending parturition in their patients.

First stage of labor

The duration of the first stage of labor in cattle is in the range 4–24 hours. The difficulty of identifying the commencement of the first stage in all species makes accurate measurement of its length unreliable. External signs of the first stage include apparent discomfort, cessation of eating, pawing the ground, paddling, circling, lying down and then fairly quickly rising again. The tail may be raised, there may be muscle tremors and occasional straining. The cervix begins to soften and dilate. When fully dilated it is not recognizable on vaginal examination. The onset of cervical dilation and uterine contractions cause the chorionallantois to be pushed into the vagina. The extent of its movement depends on its elasticity and the tightness of its attachment. If its movement is restricted it may rupture in situ but otherwise it may appear at the vulva as a bluish, vascular semi-transparent membrane. It may be termed the 'first water bag' although the term 'water bag' is generally confined to the amnion. Rupture of the chorionallantois causes
the release of a quantity of amniotic fluid and dampness around the maternal perineum.

**Second stage of labor**

The duration of this stage is in the range 8–3 hours. Cattle normally give birth in a recumbent position but occasionally, and especially if disturbed, may calve standing up. The calf is normally preceded by its amnion as it enters the birth canal and unless prior rupture occurs, the amnion appears as a gray–white avascular sac at the vulva. Fetal parts may be visible through the amnion, which ruptures during delivery in 80% of cases. Once amniotic rupture has occurred the intensity of straining may increase. Abdominal straining supplements the uterine contractions and as the second stage of labor proceeds the intensity and frequency of abdominal straining increases (Fig. 1.1).

The cow may bellow loudly with effort and may roll from sternal recumbency into lateral recumbency. The greatest maternal effort is apparently associated with the passage of the fetal head through the vulva but at this point the fetal thorax is also entering the maternal pelvis. Once the head is delivered the rest of the body mostly follows with ease, although in beef cattle considerable effort may be required to deliver the thorax and hips of the calf. During delivery the position of the calf may rotate approximately 45° to the right or left allowing it to take advantage of the greatest pelvic diameter of the mother (Fig. 1.2).

![Figure 1.1 Early second-stage labor in the cow. The calf's muzzle is level with the fetlock joints of the forelimb. The amnion has ruptured and the calf's tongue is protruding. The calf's position has rotated about 45° from the dorsal position.](image)

![Figure 1.2 Late second-stage labor in the cow. The fetal head and part of the shoulders have been delivered.](image)
The majority of calves are in a dorsal position in late pregnancy and during birth the calf is in anterior (95% of calves) longitudinal presentation, dorsal position, and in a posture with the head and forelimbs extended. The fetal nose is level with and rests on the fetlock joints of the forelimbs. The umbilical cord usually remains intact following delivery in the recumbent cow and may not rupture until the cow stands after calving. Unless exhausted, the cow stands up within 10 minutes of the birth of her calf and licks it. The calf lies still immediately after birth and often shakes its head before gasping and taking its first breath. If healthy, the calf should attempt to assume sternal recumbency within 5 minutes of delivery encouraged by licks from its mother (Fig. 1.3).

**Interference in normal calving**

Whenever possible, the cow should be left to calve unaided. Supervision should be close but unobtrusive. Vaginal examination should be performed if there is any departure from the normal. The calf should be born within 2 hours of the first appearance of the amnion at the vulva. Delivery time may be longer for larger calves and in some breeds, including the Charolais. Although the bovine fetus can survive for up to 8 hours during second-stage labor, this is not always the case and any delay should be investigated.

**NORMAL BIRTH IN THE MARE**

Gestation length is 330 days.

**Preparatory changes**

Premonitory signs of parturition in the mare can be very misleading. As birth approaches, mammary development, lengthening of the vulva, and relaxation
of the pelvic ligaments are seen. In some mares bead-like deposits of wax appear on the ends of the teats within 48 hours of parturition but in many mares foaling occurs without waxing. Predicting the time of birth in mares can be difficult. If milk is present in the udder a small quantity can be analyzed daily to determine the concentrations of calcium, sodium, and potassium ions. The use of these to predict the approximate time of birth is discussed under induction of birth in the mare in Chapter 15. The whole birthing process is much quicker and more violent than in cattle. Any disturbance, including excessive and obtrusive observation, can cause the mare to inhibit the onset of parturition. Once any disturbance is over, foaling may follow rapidly and be completed in less than an hour. The foal is in a ventral position until the first stage of labor, when it rotates into a dorsal position and adopts the foaling posture. The cervix is much softer than in the cow and can normally be manually dilated with ease just before foaling begins. The majority of mares foal between 6:00 p.m. and midnight.

**First stage of labor**

The duration of this stage is very variable, lasting on average 1–2 hours. The mare is restless, uncomfortable, may kick at her abdomen and shows signs of patchy sweating. The tail is raised and periodically swished vigorously downwards and sideways. The mare postures frequently and may occasionally strain as if attempting to urinate. The stage normally ends with the passage of a small quantity of fluid from the ruptured chorionicallantois.

**Second stage of labor**

This stage, lasting on average not more than 30 minutes, is signaled by the onset of intense straining. The mare normally lies down to foal flat on her side with her legs extended, if room allows. Straining continues with grunting, groaning, and often profuse sweating as the fetus enters the birth canal. During birth the foal, which is normally in anterior longitudinal presentation and dorsal position, has one of its extended forelegs about 8 cm in front of the other. The head may be longitudinally rotated during delivery. Passage of head and thorax appear to require additional straining effort. Once the foal is delivered – often still enclosed in the amnion – it lies with its hindlegs still in the birth canal. The mare lies still, temporarily exhausted for up to 30 minutes after delivery. The umbilical cord is normally unbroken when the foal is born but ruptures when the mare rises or the foal moves vigorously. Premature rupture may occur if the mare foals in the standing position.

**Third stage of labor**

The placenta is normally passed allantoic side out within 3 hours of foaling. It is mainly pushed out by myometrial contractions supplemented by occasional straining. Portions of placenta hanging behind them upset some mares and there may be some low-grade colicky pain associated with uterine contractions during the third stage. If the placenta is retained beyond 3 hours of foaling assistance may be required with its removal.

**Interference in normal foaling**

The early failure of placental support that occurs during foaling means that unless the foal is delivered within a maximum of 60 minutes after commencement of the second stage of labor there is a grave risk of fetal death. For this reason, foaling should be supervised carefully and unobtrusively. If both forelegs are equally advanced in the birth canal the risk of impact of the fetal elbows on the pelvic brim is greatly increased. If this occurs, or if there is any other delay, assistance should be rendered. The foal should be delivered within 40 minutes of the rupture of the chorionicallantois and, if it is not, the case should be investigated for dystocia.

Occasionally the chorionicallantois fails to rupture at the cervical isthmus, possibly as a result of premature separation of the membrane from the endometrium. The velvety red surface of the chorion appears at the vulva in what is sometimes termed a 'red bag birth'. This is a sign that the foal may be at risk and the chorionicallantois should be opened immediately using scissors to release the foal. Assistance with delivery should be given following the opening of the membrane.

Foals born within their amnions can free themselves by vigorous movement but should be released by breaking the membrane around the head. Avoid disturbing the mare in the immediate postpartum phase In case premature rupture of the cord occurs with the risk of neonatal maladjustment and other problems. Careful management of the placenta is necessary, especially in
heavy mares where severe metritis with laminitis may follow retention.

NORMAL BIRTH IN THE EWE

Gestation length is 147 days.

Preparatory changes

Relaxation of the pelvic ligaments occurs as birth approaches but is not visible in heavily fleeced ewes, where manual palpation is necessary to detect the changes. Lengthening and relaxation of the vulva is seen in some animals. Mammary growth with separation of the two teats occurs throughout the second half of pregnancy and colostrum is normally present in the teats within 24 hours of lambing. External signs of approaching birth can readily be overlooked in large flocks. Signs of first-stage labor are more obvious and the shepherd should watch carefully for these and monitor the subsequent birth process.

First stage of labor

This stage is believed to last 6–12 hours. The ewe separates herself from the flock and may appear restless and paw the ground. A few ewes show no signs of being in first-stage labor.

Second stage of labor

This stage lasts 8–1 hour and may be slightly longer in ewes lambing for the first time. The majority of lambs enter the birth canal in anterior longitudinal presentation, in the same posture as the calf. Some lambs are born in posterior presentation with the extended hindlimbs entering the birth canal first. Small lambs in anterior presentation may occasionally be born with one forelimb in shoulder flexion. The ewe normally lies down to lamb, straining vigorously and throwing her head up with effort and grunting as she does so (Fig. 1.4). Many ewes like to lie with their back against a wall or fence during lambing. The second stage is repeated as further lambs are born.

Figure 1.4 Second stage labor in the ewe. The ewe throws her head dorsally upwards as she strains.
Approximately 50% of lambs are born with an intact amnion.

**Third stage of labor**
The placenta is normally passed within 3–4 hours of delivery of the last lamb.

**Interference in normal lambing**
Close observation of parturient ewes is essential and a vaginal examination should be carried out in cases where there are signs of any delay in the birth process. Multiple birth should always be suspected and the ewe examined internally in cases of doubt. Litter size in ewes can be determined by ultrasonographic scan at 60–90 days of pregnancy. Ewes may be batched for management and lambing on the basis of their prospective litter size. Although a useful guide, errors in estimating fetal numbers can occur. Individual animals should always be examined carefully per vaginum if there is any doubt that parturition is complete.

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**NORMAL BIRTH IN THE DOE**
The birth process and timing of the stages is broadly similar to the ewe. Gestation length is approximately 150 days. The doe may vocalize loudly as if in great distress during normal delivery. Multiple births are very common and the possibility of further kids in utero must always be suspected.

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**NORMAL BIRTH IN THE SOW**
Gestation length is 115 days.

**Preparatory changes**
Mammary development is evident in gilts in the last third of pregnancy and becomes more obvious as parturition approaches. Milk is present in the teats within 24 hours of farrowing. Immediately before birth, probably associated with oxytocin release, squeezing the teats will cause release of jets of milk. The vulva swells and softens in the last few days of pregnancy. In older sows these changes, and relaxation of the pelvic ligaments, may occasionally appear to be excessive resulting in a tendency to vaginal and rectal prolapse.

**First stage of labor**
During first-stage labor, which can extend from 12 to 24 hours, the sow shows signs of bed making—chewing and heaping up any bedding within reach. Intervals of activity are interspersed with periods of rest and the sow usually settles down in lateral recumbency just before farrowing commences.

**Second stage of labor**
Mild abdominal straining heralds the onset of second-stage labor. Vigorous tail swishing and the passage of a small quantity of allantoic fluid precede the arrival of each piglet. Each piglet is normally expelled quite forcibly through the vulva. Approximately half the piglets are still enclosed within their amnion and those born early in the litter have intact umbilical cords. Fifty per cent of piglets are born in anterior longitudinal presentation with their forelimbs held by their sides; 45% are in posterior presentation with their hindlimbs extended backwards or less commonly in a hip flexion posture.

Usually, 3–6% of piglets are stillborn in normal litters and a small number of mummified fetuses are commonly seen. The stillbirth rate rises rapidly with increasing duration of labor and dystocia.

The mean farrowing time is 2½ hours (range 1.5–4 hours), with piglets born at intervals of approximately 15 minutes. The sow may rise at intervals during farrowing but mostly remains recumbent until delivery of the last piglet.

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**Third stage of labor**
Portions of placenta may be passed after each piglet, after a number of piglets, or at the end of farrowing. The chorioic surface of the last pieces of placenta from each horn may be a darker red color than the remainder of this tissue. After farrowing is complete the sow may rise, pass urine, and then lie down to continue feeding her piglets. However, these signs are not reliable indicators that farrowing is complete.

**Interference in normal farrowing**
Piglets may need assistance to escape from their amniotic sacs and be protected from injury if the sow stands during parturition or shows signs of aggression. Any delay in parturition must be investigated to ensure early diagnosis and treatment of dystocia and to avoid high
levels of stillbirth. On many pig farms, birth is induced by intramuscular injection of prostaglandin F2 alpha or a synthetic analog. Healthy sows within 48 hours of their prospective farrowing date are induced and normally farrow 20–30 hours later. Treatment is given in the early to late morning and staff are able to supervise farrowings during working hours the following day. A reduction of stillbirth rate and a reduced preweaning mortality should result. On some farms, once farrowing is underway its conclusion is hastened by an intramuscular injection of oxytocin. This should only be done in animals in which it is known that cervical dilation is complete and in which there is no obstructive dystocia.

NORMAL BIRTH IN THE BITCH

Gestation length is 63 days.

Preparatory changes

In maiden pregnant bitches, mammary development may occur as early as 3–4 weeks into gestation. In late pregnancy mammary development becomes more pronounced but the onset of lactation is extremely variable. In some bitches milk may be found in the teats 2 weeks, and occasionally even earlier, before whelping. In others there may be no sign of milk in the teats until whelping is actually under way.

In the last week of pregnancy the vulva becomes enlarged, elongated, and rather flabby, and there may be a little clear vaginal discharge. In some bitches, however, this discharge is present throughout pregnancy. Relaxation of the pelvic ligaments and abdominal musculature occurs in the last few days of pregnancy. The most reliable sign of impending parturition in bitches is the fall in body temperature of up to 1°C that occurs within 24 hours of whelping.

First stage of labor

The signs of this stage are very variable both in intensity and duration. They may extend over 4–24 hours. The bitch is restless and may show a strong desire to make a nest under tree roots, under furniture, or on the owner’s bed. Pawing, shivering, panting, flank watchfulness, and occasionally vomiting and mild straining may be seen. The signs normally show a steady and progressive increase in intensity as second-stage labor approaches. Nervous bitches often experience a more stormy first stage than their more placid counterparts and may refuse to settle down or be separated from their owners. Familiarization with the whelping quarters well before birth may help reduce the problem. Mild sedation may be necessary. Very occasionally no external signs of first stage are seen.

Second stage of labor

The bitch usually lies in lateral recumbency during delivery but occasionally walks around pausing to strain in a squatting position. The chorionallantois of each pup normally ruptures at the pelvic inlet allowing the amniotic sac to enter the pelvic canal. A small quantity of allantoic fluid may pass out through the vulva at this stage before delivery of the puppy. The puppies rotate through 180° to assume the dorsal position of birth. Sixty per cent are born in the anterior longitudinal presentation and 40% in the posterior presentation (Fig. 15). Posterior presentation is often erroneously referred to by dog breeders as a “breech birth”. In a true breech birth, the tail and hindquarters of the puppy are presented with both hind legs in hip flexion.

Once the presenting part of the fetus has engaged in the pelvis, reflex abdominal straining commences and the puppy is usually delivered with relative ease after two or three expulsive efforts. Straining may be particularly intense in small breeds with small litters where there is a degree of fetopelvic disproportion. The first puppy should be born within 6 hours of the commencement of second-stage labor. The interval between puppies is 5–60 minutes (average 30 minutes), tending to be longer near the end of the delivery of the litter. The interval between puppies can be as long as 4 hours without it necessarily being abnormal. Ideally, the intervals should be shorter and of even length. Some bitches regularly take up to 24 hours to complete whelping successfully but they must be closely supervised. During delivery a dark green discharge accompanies the puppies and arises from the breakdown of the marginal hematoma of the zona pellucida. During delivery the bitch’s respiratory rate may become very shallow and rapid (150 per minute) and may be exacerbated by excessive heat or poor ventilation in the whelping quarters. Inexperienced bitches may stand during delivery of one or more of their litter and there is a small risk that they may accidentally tread on other members of their litter.

As soon as each puppy is delivered the bitch normally licks its head and opens the amniotic vesicle if this has not occurred spontaneously. The bitch severs
the umbilical cord with her teeth about 2 cm from the puppy. Between puppies, the bitch may lapse into a somnolent state until the next puppy enters her pelvis. She will often rouse herself at intervals from her resting position to lick and clean the pups or her vulva. Muscle fasciculations resembling shivering are sometimes seen in the hindlimbs but there is normally no sign of hypothermia.

**Third stage of labor**

The choriovitellots may be delivered after each puppy, after a group of puppies or at the end of whelping. The bitch will often eat each placenta as it is passed but this may cause vomiting. Owners frequently suspect that one or more placentas have been retained having failed to observe the bitch eating them. The duration of the third stage is very variable but should be completed within 2 hours of the delivery of the last puppy.

**Interference in normal whelping**

As in other species, observation should be careful but discreet. Steady progress in whelping is anticipated and care taken to ensure survival of the puppies by ensuring their release from the amniotic vesicle and avoiding accidental or careless damage by the bitch. Excessive interference must be avoided.

**NORMAL BIRTH IN THE QUEEN CAT**

Gestation length is 63 days.

**Preparatory changes**

Activity is often reduced in the last week of pregnancy and the cat seeks a quiet, dark, warm area in which to give birth. Normal activity is maintained in some cats, which happily climb trees within hours of giving birth. Some change in temperament may be seen with the cat, either seeking or shunning human company. Appetite may be reduced in late pregnancy. Sudden intra-abdominal fetal movements may appear to cause her alarm. Relaxation of the pelvic ligaments and the abdominal musculature occurs as parturition approaches. Mammary development intensifies, the teats become pink, and milk is present within 24 hours of birth.
Body temperature in the queen falls by 0.5–1°C within 12 hours of birth.

**First stage of labor**

During this stage the cat appears restless and may vocalize frequently. Nesting behavior becomes increasingly intense, with the cat tearing up or rearranging her bedding. She may visit her litter tray frequently and strain unproductively. Many domestic cats choose to give birth away from home. Duration of the first stage is variable at 2–12 hours.

**Second stage of labor**

The first kitten is normally born within 5–60 minutes of the commencement of abdominal straining – the longer period being seen in some primiparous cats. A series of loud cries may accompany fetal delivery, especially the first kitten, and may alarm the inexperienced owner. Subsequent kittens are born at 5 to 60 minute intervals and the second stage is normally complete within 6 hours. Great variation in the duration of second-stage labor is seen and long pauses – sometimes lasting several hours – may occur, extending the birth process to 24 hours without loss of fetal life. During kittening the cat may rise suddenly from her recumbent position to lick her vulva and move around in her quarters. It has been suggested that these sudden movements may increase intra-abdominal pressure and hasten fetal delivery. During delivery, a dark brown discharge is normally seen, which arises from the breakdown of the marginal hematoma of the zonary placenta. Once each kitten is delivered the queen licks it and removes any residual portions of the amnion (Fig. 1.6).

**Third stage of labor**

The placenta may be passed after each kitten, after one or two kittens or at the end of the second stage. The process is normally completed within 2 hours of kittening. If unattended, the cat will consume the placentas which may cause vomiting.

![Image](image.png)

*Figure 1.6 The queen cat removes remnants of amnion from her newborn kitten.*
Interference in normal kittenning

As many cats give birth away from home, close supervision is often not possible and problems may not be discovered until the cat returns home with or without her kittens. The great variation in normal behavior can make monitoring progress difficult but any sign of maternal distress or unexpected delay should be investigated. Some kittens may require assistance in breaking free from their amniotic sacs. Inexperienced cats may fail to sever the umbilical cords of their kittens, which may become entangled with each other’s cords. Careful dissection with scissors is required to free them.

THE FATE OF THE FETAL MEMBRANES

The fetal membranes are usually consumed by the mother (with the exception of the mare) if she has access to them shortly after the completion of second-stage labor. The herbivorous ruminant species rarely suffer any adverse effects if they eat their placenta. On many farms, however, they are collected and disposed of as soon as possible after birth has occurred. Small animals normally eat their placentas but many breeders do not encourage this, preferring to collect and dispose of them.

CHANGES IN THE FETUS DURING THE PERINATAL PERIOD

The fetus that has been protected and nourished within the maternal uterus throughout pregnancy has to undergo major changes at the time of its birth. Once contact with the placenta is severed by rupture or compression of the umbilical cord, the fetus must breathe or it will die. During delivery the fetus may have become hypoxic as it passed through the confines of the birth canal. Less well-developed fetuses, such as those of the dog, may be able to withstand a degree of hypoxia for a longer period than more highly developed fetuses, such as those of the large ruminants. The fetus has practiced breathing movements during pregnancy. Increasing levels of fetal cortisol will have encouraged surfactant production in the lungs to reduce surface tension and facilitate postnatal breathing and gaseous exchange. The developing hypoxia during its birth, exposure to air, and a lower ambient temperature after its birth causes the fetus to gasp and expand its lungs for the first time.

Application of mild pain, such as pinching the nose or feet or splashing cold water on the head, will also encourage the fetus to gasp. After the first gasp, other gasping movements may be made before normal breathing commences. Fluids within the fetal lungs are absorbed and may be drained away or coughed up from the trachea. Removal of fluids can be aided by raising the hind end of the fetus to facilitate drainage or by application of suction.

Shortly after birth, closure of the ductus arteriosus and the foramen ovale increases the blood supply to and from the lungs. Retraction of the severed umbilical blood vessels occurs shortly after birth. The ductus venosus, which allowed the umbilical vein bringing oxygenated blood back from the placenta to bypass the liver during pregnancy, closes and the hepatic portal circulation becomes fully functional. The urachus is sealed and all urine is now voided through the urethra. Fetal hemoglobin is replaced by adult hemoglobin.

During its intrauterine life, fetal body temperature is maintained by contact with maternal tissues. After birth the fetus is vulnerable to hypothermia. Although there is some variation between the species, most fetuses have deposits of mitochondria-rich brown fat: piglets are born with very small reserves of brown fat. Metabolization of brown fat releases heat and energy in the first few hours of life, helping the neonate to maintain body warmth and survive. Lack of its mother helps to dry the fetal coat and in many species the fetus also seeks warmth and shelter from its mother. Shivering can occur in some neonates, such as calves, within a few hours of birth. Puppies are unable to shiver effectivly to generate body heat until they are 2 weeks old, making them particularly susceptible to hypothermia in the neonatal period.

The newborn must seek maternal milk and access to this is helped by a caring and experienced mother. Colostrum transfer and nourishment are vital postnatal events. Rising levels of fetal cortisol in late pregnancy are thought to cause maturation of thyroid and pancreatic function, enabling glucose homeostasis to be maintained.

CHANGES IN THE MOTHER IN THE POSTPARTURIENT PERIOD

Following fetal birth a number of important changes occur, especially in the maternal reproductive system. These include involution of the uterus, removal of placental and other debris from the uterus, closure of the cervix, restoration of the endometrium, and resumption of sexual activity. There is great variation between the domestic species in the timing of these events. In the mare, for example, overt ovulatory activity is evident at the foal heat 5–10 days after foaling. In the seasonally monestrous bitch, overt ovulatory activity might not be seen until 4–6 months after whelping.

Postparturient events have been particularly well documented in the cow. Involution of the uterus commences immediately after calving and is complete by 25–50 days. Urine fluids have disappeared by 7–10 days. The cervix closes within 24 hours of normal calving. The caruncles slough from the endometrium by 10 days after calving and are restored by 25 days. Ovarian activity commences at 10–14 days after calving and breeding can occur at 40–80 days.

In addition to these events, the maternal body has to respond to the demands of lactation and restore the antibodies lost through colostrum transfer.
Fetal mummification

One possible fate of the fetus that dies in utero is that it will remain in the closed uterus. Its fetal and body fluids will be resorbed and it will become mummified. The corpus luteum normally remains active and the dam does not return to estrus. In most cases the mummified fetus becomes dry and paper-like (papyraceous mummification). In cattle, another form of mummification, possibly of genetic origin, has been seen in Channel Island breeds. Hemorrhage occurs between the chorion and the endometrium, possibly as a consequence of fetal death and the dead fetus becomes surrounded by sticky fluid. This is sometimes known as hematic mummification.

Fetal mummification occurs in all species. In the polytocous dog, cat, and pig a number of fetuses may become mummified but the rest of the litter remains normal. A number of small mummified fetuses may be delivered along with the normal living fetuses at term. In the mare, one member of a pair of (undesirable) twins may die and become mummified as the fetuses compete for uterine space. Eventually – often at 7 months into pregnancy – both twins may be aborted, one alive but unviable through prematurity and the other mummified. In the ewe, mummified fetuses are occasionally diagnosed when those members of the
flock that have not lambed are checked after lambing. Treatment is as in the cow (see below) but in many cases such animals are culled.

**Fetal mummification in the cow**

**Clinical signs** Fetal mummification is mostly detected on rectal examination of the cow that has either passed her prospective calving date or does not look as heavily pregnant as her dates suggest. The uterus feels tight and the fetus hard to the touch. There are no cotyledons and no fremitus in the uterine arteries. A corpus luteum may be palpable in an ovary and blood progesterone levels are elevated. The obstetrician should beware of possible confusion with other intra-abdominal masses, for example fat necrosis. Ultrasonographic scan through the rectal wall will be helpful in confirming the diagnosis. The fetus will normally remain in the uterus for as long as the corpus luteum persists. Occasionally, spontaneous regression of the corpus luteum occurs and the mummified fetus may pass into the vagina and the cow returns to heat. Mummified fetuses are occasionally seen during routine meat inspection.

**Treatment** An injection of prostaglandin F2α analog (for example 500 μg cloprostenol) is given to lyse the corpus luteum. It regresses, the cow comes into oestrus, the cervix opens and the fetus passes into and lodges in the vagina usually within 2–3 days. It must be removed with care from the vagina by gentle traction using plenty of lubrication. Other treatments have included the use of estradiol injections or cesarean section. Access for the latter would be difficult and prostaglandin F2α or its analogs remain the treatment of choice.

**Prognosis** The prognosis for recovery and future fertility is good.

**Fetal maceration**

This occurs if fetal death is accompanied by loss of the corpus luteum. Opening of the cervix and entry of autolytic and other bacteria into the uterus. The fetus decays in the uterus and its soft tissues break down and are passed as a foul vaginal discharge. In many cases the bones are too large to pass through the cervix and are left in the uterus normally preventing subsequent conception. Sharp fragments of bone may become embedded in the endometrium and endometritis occurs in some cases. Fetal maceration can also occur in full term fetuses that fail to leave the uterus, for example in sows.

**Clinical signs** There is a foul-smelling vaginal discharge in an animal thought to be pregnant. In cattle it may be possible to palpate sharp bony fragments within the uterus during rectal examination. Fragments of bone may also be detected protruding from the cervix into the vagina. They can also be detected by ultrasonography. In small animals bony fragments can be detected by X-ray.

**Treatment** This is often unsatisfactory because it is difficult to remove bony fragments from the uterus. If access by the fingers through the cervix is possible in the larger species, bony fragments may be removed and uterine lavage performed. Some success has been achieved dilating the cervix in valuable cattle by daily local application of prostaglandin E. In sheep, hysterotomy has been employed but is seldom economically justified. In the smaller species hysterectomy may be required and this has also been attempted in gilts suffering from the toxic form of primary uterine inertia (see Chapter 8).

**Prognosis** The prognosis for complete resolution and future fertility is guarded.

**HYDROPS UTERI**

The term implies excessive amounts of fetal fluids within the pregnant uterus. The fetus itself may or may not be edematous and may show anasarca, hydrothorax or ascites. Two forms of hydrops uteri have been described (depending on the site of excessive fluids): hydrops amnion and hydrops allantois. In some cases it is not possible to be sure which of the fetal sacs is involved. Hydrops uteri is estimated to occur in 1 in 7500 bovine pregnancies. The incidence appears to be falling although the reasons for this are not clear.

Hydrops has been reported in most of the domestic species but is most common in the cow and has been well documented in this species and in the mare.

**Hydrops amnion**

**Incidence** The condition is mostly sporadic but there may be groups of several cases in a herd.

**Etiology** The condition is often associated with an abnormality of the fetus, especially cleft palate (the calf may fail to swallow its amniotic fluid). Other


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<th>Table 2.1 Characteristics of hydrops amniot and hydrops allantois</th>
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coincidental abnormalities include pituitary hypoplasia in Guernsey cattle and bulldog calves in Dexters.

**Clinical signs** Nothing might be seen until calving when there appears to be more amniotic fluid (syrupy consistency) than normal. If the uterus is very distended contractions may be weak and assistance is required with delivery. Other cases may have excessive abdominal enlargement and the owner may suspect twins. The cow may show some difficulty getting up due to increased weight as pregnancy progresses.

**Diagnosis** Rectal examination may assist in evaluation of signs. The uterus is large and it may be possible to palpate the fetus and the cotyledons are normal to the touch. Ultrasonographic scan of the uterus may indicate that relatively large amounts of amniotic fluid are present but this may be difficult to visualize or interpret with certainty at the stage of pregnancy at which hydrops amnion is seen. Excessive quantities of amniotic fluid are noted at birth. The calf may be deformed and placenta may be retained (as happens with other forms of uterine distention and inertia). Differential diagnosis: other causes of abdominal enlargement.

**Treatment** If the cow is bright and active she may need no specific treatment but assistance may be required at calving. If the cow is distressed it may be necessary to terminate her pregnancy by an injection of prostaglandin F2α (see the further discussion of treatment under hydrops allantois).

**Hydrops allantois**

**Incidence** The condition is mostly sporadic but there are occasional reports of the same cow being affected twice. The overall incidence of the condition may be falling.

**Figure 2.2** Hydrops allantois in the cow, showing gross abdominal distension.

**Etiology** This is not clear. Placental abnormalities have been blamed and possible interference with sodium metabolism at cell level suggested.

**Clinical signs** The onset is often rapid and the condition may be life-threatening. The abdomen is enlarged and tense but the cow herself looks ill and is often in poor bodily condition despite her large size (Fig. 2.2). The uterus is massively enlarged and may contain >200 L of fluid with a resultant enormous increase in body weight. Abdominal pressure is greatly increased: Breathing may be labored, appetite depressed, and complications such as rectal or vaginal prolapse, hip dislocation, rupture of the pubic tendon, and recumbency may follow. On rectal examination the uterus is grossly enlarged and apparently filling the entire abdomen and pushing backwards and upwards into the pelvic cavity. Numerous very small accessory cotyledons are palpable but the fetus is mostly inaccessible to touch.
Ultrasonographic scan of the uterus per rectum reveals excessive quantities of allantoic fluid and the numerous small cotyledons, which are features of the disease.

**Diagnosis**  The clinical signs, a sudden severe onset and specific rectal findings are usually diagnostic. Differential diagnosis: normal twin pregnancy, hydroptic abortion, ruminal tympany, abdominal disorders, peritonitis, ascites. Abdominal paracentesis - aspiration of fluid that can be identified as allantoic fluid - is present (see Table 2.1 for composition).

**Prognosis**  The prognosis is extremely guarded.

**Treatment Considerations**  (1) prospective calving date; (2) condition of the dam, especially her ability to rise and eat; (3) viability of the calf (if known); (4) relative value of the cow and calf; (5) the availability of nursing care.

**Methods**  (1) conservative (await developments), possibly the best course if the cow is in reasonable health and her calving date near; (2) diuresis - not very effective; (3) uterine drainage - temporary relief but the uterus rapidly refills and there is a risk of infection; (4) induction of birth - risk of losing a premature calf and the obstetrician will probably have to deal with uterine inertia if birth is induced. Induction may be achieved by administration of 20 mg dexamethasone by intramuscular injection. This is followed with an intravenous drip of oxytocin (Long 2001) given over a period of 30 minutes. Manual assistance with delivery may also be necessary; (5) elective cesarean section, possibly with partial drainage of the uterus before surgery. There is a risk of shock when the uterus is emptied but this is not a serious problem because the fluid is extracellular. Sudden loss of abdominal pressure could however lead to splanchic complications. The fetus is usually very small and poorly developed but sometimes survives.

**Hydrops allantois in the mare**

The condition is quite rare. Most cases have a sudden onset at approximately 7 months gestation. Massive abdominal distension and colicky signs are seen. Rectal examination reveals gross uterine enlargement and tension: the fetus is seldom palpable. A transabdominal ultrasonographic scan reveals the presence of excessive quantities of uterine fluids. Fetal viability can be ascertained by ultrasonography if the fetus can be located.

**Treatment**  Abortion is induced as a life-saving treatment: prostaglandin F2alpha is used to induce birth. In early cases no other treatment may be necessary. In later cases the obstetrician may manually dilate the cervix, puncture the chorionallantois, and deliver the foal. Allantoic fluid is drained from the uterus via the cervix, before and after fetal delivery. Intravenous fluid therapy is administered if the mare shows signs of shock. Uterine involution and delivery of the placenta are assisted by administration of 20–30IU oxytocin. The foal is often deformed - a cerebellar or a cerebral abnormality are often present - unlike the cow where the calf is usually normal. In some cases the uterus may contain nearly 100L of allantoic fluid with the foal. Mares may breed again normally the next year.

**Hydrops uteri in other species**

Occasional reports in other species include the sheep and dog. The condition is not well documented and may be hydrops amnion. It is seldom life threatening but may need relief in the form of cesarean section or treatment of associated uterine inertia at term.

**RUPTURE OF THE UTERUS DURING PREGNANCY**

This may be less serious than rupture during or after fetal delivery. The event may pass unnoticed as the uterine contents are normally sterile and not likely to induce peritonitis. The consequences may be serious if hemorrhage or a crushing injury occurs at time of uterine rupture. In a road accident a dog may sustain multiple injuries including a ruptured uterus, which may be discovered at a laparotomy carried out to investigate serious abdominal bleeding.

If the fetus passes into the peritoneal cavity (see Ectopic pregnancy, above) it will be unable to be delivered normally and will require surgical removal at term.

The uterus of sheep and goats is particularly fragile and great care must be exercised whenever heavily pregnant animals are handled. This is necessary to avoid damage which could be fatal as a result of shock and/or hemorrhage.

**RUPTURE OF THE VAGINA**

Seen chiefly in sheep, this condition may be encountered as a series of cases in a flock. In one study (Knottonbelt 1988) 17 cases were reported. Of these 10 were found dead, six had to be destroyed, and one died after surgery. All had a tear in the dorsal vaginal wall.
and had suffered partial eversion of the defect (Fig. 2.3). The ewes shared a number of common features: Most were in poor condition, all carried more than one lamb, all had elevated blood urea and betahydroxybutyrate, most were aged 3–6 years, and all had low caesium levels. Blood estrogen and progesterone levels were normal. Some had suffered prior vaginal prolapse. The prognosis in living patients should be very guarded.

**Treatment** If spotted early, surgical repair may be possible but vital tissues might be already compromised. Euthanasia is indicated in morbund animals.

**Prevention** This is difficult because the cause is unknown. Exercise during pregnancy and careful feeding with suitable mineral supplementation may help prevent the condition.

### Herniation of the Pregnant Uterus

In this condition the uterus passes into an existing hernia or an acquired rupture. Any abdominal hernia may be involved. The uterus can be trapped in the hernia by the fetus growing too big to pass back into the abdomen. In the case of large hernias the efficiency of abdominal straining at term may be compromised and assistance in both circumstances will be required.

### Inguinal Hernia

This hernia is seen chiefly but rarely in the bitch. The original hernia may be acquired or congenital. It may pass unnoticed until pregnancy. A swelling is seen in the inguinal region and may be reducible at an early stage. In most cases the uterus enters the hernial sac but as the fetus grows its size exceeds that of the neck of the hernia. The fetus may die if the blood supply is compromised but if it is diagnosed promptly the hernia can be explored surgically, the trapped uterus released and the hernia repaired. If problems occur at parturition the hernia may be emptied during cesarean section.

### Diaphragmatic Hernia

This rarely contains the pregnant uterus and is repaired in the standard way. If the patient attempted to give birth while suffering from this hernia the efficiency of straining would be compromised.

### Ventral Hernia

This is chiefly a problem in heavily pregnant large animals but is occasionally seen in old cats or dogs with weak abdominal muscles. The weight of a multiple pregnancy may predispose as – rarely – may excessive straining at parturition. (A massive subcutaneous hematoma in the udder of a sow may give the false appearance of a hernia.) Abdominal muscles give way under the increasing weight of the uterus, which is then only supported by skin and subcutis. Total rupture of abdominal floor and eversion is fortunately extremely rare. The efficiency of straining is greatly compromised and uterus may ‘hang down’ at an abnormal angle in the hernial sac. Surgical repair is seldom possible and it may be necessary to supervise and assist with fetal delivery and possibly with feeding of the newborn. Affected animals are normally not retained for breeding.

### Perineal Hernia

This is occasionally seen in pregnant sheep close to term. The hernia seldom contains the uterus but may interfere with the efficiency of delivery and assistance with this is required. Repair is not normally attempted in large animals.

### Rupture of the Prepubic Tendon

This is seen chiefly in the heavy horse but occasionally in other farm species. The prepubic tendon ruptures as a result of the great increase in tension that accompanies advancing pregnancy. The condition and threatened condition are mostly accompanied by gross edema just anterior to the udder (Fig. 2.4). The edema is characteristically painful, unlike the ‘normal edema’ that often accompanies approaching parturition in horses (and in lesser extent other animals). The obstetrician may be able to palpate the compromised tendon per rectum in smaller mares. Little can be done in large animals once the tendon has actually ruptured but if it is believed to be at risk of rupture the ventral abdomen may be supported with a canvas sling attached to the animal’s back supporting the ventral area. Parturition in such cases must be supervised and aided to avoid excessive straining. In some cases it may be possible to terminate pregnancy and risk to the tendon by induction of birth.

Damage to the pubic attachment of the abdominal muscles has been reported in cats, mostly as the result of road traffic accidents. Abdominal straining may be compromised in affected animals but surgical repair is often possible.

### Prolapse of the Vagina During Pregnancy

Prolapse of the vagina is an important and common condition requiring careful management. It is seen chiefly in cow, ewe, and sow; less commonly in mare, doe, bitch, and queen.
Etiology  Excess ante partum relaxation of pelvic tissues and increased intra-abdominal pressure.

Predisposing factors  These include: breed in cattle (there is a high incidence in Hereford cows); high levels of estrogen in the diet (for example in some clovers); possible high endogenous production of estrogen; slating environment; ruminal tympany; overfeeding with bulky food. Other factors include aging – the pelvic muscles and ligaments become less elastic with successive pregnancies.

Clinical signs  Eversion of the vagina with exposure of the mucosal surface (Fig. 2.5). In the early stages the appearance of the prolapse may be intermittent. The prolapse may be partial or complete and in the latter case the cervix may also be visible. The exposed organ is vulnerable to damage and possibly infection. Small animals may cause additional damage by licking the prolapsed organ. The sow may rub her hindquarters against the bars of her farrowing crate. In all cases the obstetrician must ensure that it is the vagina, and not the rectum, that is involved – sometimes both are affected.

Treatment

1. Aims  To prevent further damage to the organ, replace it after appropriate cleaning, supervise birth, and be prepared for possible postpartum recurrence.

2. Considerations  Severity of prolapse, species involved, proximity of parturition, extent of damage sustained.

3. Methods

- Conservative: If the prolapse is intermittent or slight the obstetrician or attendant may simply clean, lubricate, and replace the prolapse periodically while awaiting birth. Parturition is then carefully supervised to avoid further damage to the prolapsed organ. In the cat and dog it may help to put a protective collar round the patient’s neck to prevent licking. A cow may be placed in a stall with an elevated rear end so that her hindquarters are higher than her head. The forces of gravity may assist in keeping a small prolapse in place. In other cases repeated injections of epidural anesthetic combined with xylazine have been used to prevent straining, with varying degrees of success.

- Suturing methods/trusses: numerous suture patterns are available including a simple mattress suture and Buhner’s purse-string suture (Fig. 2.6). In each case, careful cleaning of the prolapse and administration of epidural anesthetic is required. In sheep, a plastic vaginal truss or prolapse trainer (‘Moffat’ trainer) is very effective and is usually tied onto the fleece on either side of the perineum (Fig. 2.7). The ewe is able

Figure 2.5  Vaginal prolapse in a doe goat.

Figure 2.6  Buhner’s suture for retention of vaginal prolapse.
THE Puerperium

The puerperium is that period after the completion of parturition, including the third stage of labour, when the genital system is returning to its normal non-pregnant state. In the polyoestrous species (the cow, mare and sow) it is important that there should be a normal puerperium since it is the practice under most systems of husbandry to breed from individuals of these species fairly soon after they have given birth. Thus any extension of the puerperium may have a detrimental effect on the reproductive performance of the individual animal concerned. The genital system does not completely return to the original pregravid state since, particularly after the first gestation, certain changes are not completely reversible.

The postpartal period is defined as the interval from calving to complete involution and consists of three phases:

1) The "early postpartum period" lasts about 8 to 14 days until the pituitary gland becomes responsive to GnRH;
2) The "intermediate period" begins when the pituitary becomes responsive to GnRH and lasts until the first ovulation; this period is very variable, but in many cows, lasts until Days 12-25 p.p.;
3) The "postovulatory period" which extends from the first ovulation until uterine involution is complete at around 40 to 50 days postpartum.

After parturition, involution of the uterus is characterized by marked changes in uterine size, vaginal discharge and morphology of the endometrium. At about three weeks p.p., the uterus has reached the size of the non-pregnant status, and by 6 weeks p.p., the repair of the endometrium at the caruncular site has been completed. Under normal conditions, uterine fluids have been expelled by Day 18 postpartum. During parturition, bacteria can enter the uterus through the open birth canal. In fact, bacterial contamination can be detected in up to 90% of dairy cows during the first postpartum week. In addition to the intraterine defense mechanisms, by which bacteria are killed and digested, postpartal uterine contractions help to eliminate the bacteria by causing an outward flow of fluids. In most cases, bacteria are eliminated within 10 days p.p without causing any clinical symptoms. A retarded involution, a heavy bacterial load and/or a weak intraterine defense
usually result in the inflammation of the uterus, i.e. endometritis develops, which might persist beyond the puerperium.

**Physiological basis of puerperium**

There is a transient increase in FSH 2–3 days after parturition followed by the re-establishment of waves of follicular growth. Normally, one follicle from each wave achieves dominance, as described in Chapter 2, the first dominant follicle being present by about day 10 postpartum. It is by no means certain that this will initiate ovarian cycles, since a number of other conditions need to be met before a dominant follicle will ovulate:

- LH pulse frequency. This has been shown to be higher in cows that ovulate their first dominant follicle, suggesting that a threshold frequency is necessary to induce final follicle maturation and/or produce the ovulatory peak. Pulse rate is lower in cows that are still in negative energy balance, those that produce more milk and those with hypoglycaemia. Data from sheep indicate that exogenous IGF-I increases LH release and that circulating IGF-I may alter the sensitivity of the pituitary to LHRH and to oestradiol feedback, suggesting that IGF-I is the mediator for metabolic influences on LH release.

- Oestradiol secretion. A dominant follicle needs to produce sufficient oestradiol to trigger an LH surge and ovulation. Our own studies in beef cows have shown that the pituitary gland is able to release a normal preovulatory surge of LH in response to exogenous oestradiol by day 14 postpartum.

- Insulin-like growth factors I and II (IGF-I and IGF-II). Systemic IGF-I, in addition to its effect on LH release, acts with locally produced IGF-II to encourage proliferation of smaller follicles in particular. IGF also enhances ovarian oestradiol and progesterone production.

- Insulin. The effects of insulin overlap to an extent with those of IGF-I, but insulin has a specific effect in stimulating oestradiol production by the follicle.

- Leptin. Decreased levels of this 16-kDa protein, produced in the fatty tissues, have been linked to delayed resumption of cyclicity and it is thought to be a further metabolic signal linking metabolism to reproductive performance. At the cellular level, leptin appears to inhibit the action of insulin on steroidogenesis and the stimulation of androgen production by LH.

**Progesterone as an indicator of ovarian function**

Progesterone is secreted by a non-ovulated ovarian follicle that has undergone a degree of luteinization, or by a normal corpus luteum that is unable to respond maximally to the luteotrophic stimulus of luteinizing hormone (LH). It has also been suggested that this rise is preceded by an ovulation and that a premature release of PGF2a from the uterus results in premature luteolysis. In some postpartum situations, insulin levels may be sufficient to promote oestradiol production, whilst IGF-I levels may not be sufficient to induce follicle proliferation. This may result in the ovulation of a small follicle, which in turn may produce a small corpus luteum, which could thus be of short duration. The possibility exists that this first short cycle primes the endocrine system to secrete gonadotrophins so that normal ovarian cyclic function is then stimulated. However, the short cycle is not an essential prerequisite for normal cyclicity as all cows do not undergo it. Although it is not normal for oestrus to be exhibited at the beginning of the first cycle, studies at the University of Nottingham have shown that both dairy and beef cows are able to conceive to service before any...
rise in milk progesterone concentrations. It thus appears that oestrous behaviour and ovulation can often precede any postpartum rise in progesterone concentrations.

**Factors affecting the postpartum acyclic period**

**Suckling**

Many studies have shown that the onset of ovulation and/or oestrous behaviour can be delayed longer in both dairy and beef-type cows that suckle calves than in milked animals. Dairy cows resumed ovarian cycles (as determined by milk progesterone measurements) after 24.0 ± 0.6 days postpartum. In our study of 2364 cows, over 80% had resumed ovarian cycles by day 30 postpartum and 95% by day 60. In suckling beef cows, however, the time to resumption of ovarian cycles was 59.9 ± 2.5 days after calving and there was considerably more variation both within and between herds. Calf removal, either temporary or permanent, or the prevention of suckling by the fitting of nose-plates to the calves has been reported to shorten the acyclic period. Mastectomy of cows (removal of the udder) also shortens the acyclic period relative to non-suckling. This suggests that the presence of the udder itself may be inhibitory to ovarian activity, in addition to any specific effect of suckling. Increasing the suckling intensity by double or multiple suckling (two or more calves per cow) has been reported to increase the postpartum acyclic period in some circumstances, although in our experiments we observed no difference between single- and double-suckled beef cows. These experiments and those using the multiple-suckled Friesian cow as a model for the study of endocrine patterns in the postpartum anoestrous cow have shown a wide variation in the length of the acyclic period from less than 15 days to in excess of 100 days. Varying the suckling intensity by restricting suckling to twice daily versus suckling ad libitum does not appear to affect the acyclic period significantly. We showed that the pulsatile LH pattern reappears in milked dairy cows from about day 10 postpartum, whilst in the multiple-suckled Friesian cow it may not occur until day 50 or later. The situation in the single- or double-suckled beef cow appears to be intermediate between the two extremes. This is in line with suggestions that the onset of ovarian cycles is delayed in some suckling cows due to an inhibition of pulsatile LH release. High prolactin concentrations inhibit ovarian activity in the human and in the ewe. They have also been implicated in the inhibition of ovarian activity in suckling cows, since it has been a widely held belief that suckling of calves induces hyperprolactinaemia. However, experiments have shown that plasma prolactin concentrations in suckling cows are no higher than those in milked or non-suckling cows. Furthermore, the pattern of gonadotrophin secretion in cows was not affected either by suppression of plasma prolactin concentrations with the dopamine agonist bromocryptine or by infusion of exogenous prolactin.

**Milk yield**

Associations between high milk yield and reduced fertility have been reported for many years, but whether reproductive performance is directly affected by milk yield remains debatable. Increasing yields in the UK and USA have been reflected in reduced fertility, and longer acyclic periods have been observed in cows selected for high milk yield relative to control animals, but it is difficult to separate the effects of milk yield from other confounding factors, particularly that of nutritional status. For example, high-yielding cows in early lactation are often unable to maintain a state of positive energy balance despite high levels of feeding. In fact, it could be stated that yield is not a risk factor for reproduction. There is even less clear evidence as to the effect of milk yield on the time to onset of postpartum cyclicity. Again, milk yield is confounded with other.

**Nutrition, body weight and body condition**
The interaction between nutrition and overall fertility performance is very complex, and many experiments have produced conflicting results. The above discussion indicates the importance of nutrition in the initiation and maintenance of reproductive cycles and some of the mediating factors. The influence of nutrition is confounded with not only milk yield, but also many other factors, such as season and suckling. Energy intake appears to be more critical than protein intake in the maintenance of reproductive function as positive relationships between energy intake factors, such as lactation number. First lactation cows produce less milk, but they eat less and have higher requirements for growth, so that their energy balance is different. When 400 dairy cows (half of which were in their first lactation, and assessed separately) were monitored using milk progesterone profiles there was a significant positive relationship between the interval to first ovulation and both peak and total milk yield, and reproductive performances have been demonstrated in several studies. Low energy intake in pre- and postpartum cows increases the length of the anoestrous period and in heifers has been shown to result in fewer ovarian follicles, lower progesterone levels and lower conception rates. The use of body condition scoring techniques has played an important role in the monitoring of nutritional status in cattle. This technique, although somewhat subjective, is simple to perform, requires no specialized equipment and has the advantage that unlike body weight it is independent of skeletal size. Target body condition scores for cows at different stages of the reproductive/lactational cycle have been published and validated over many years. Nutritional status also appears to be critical in determining conception rate at mating. Positive relationships between nutritional status, body weight and body condition score and fertility in both dairy and beef cows have been documented. Although dietary energy supply is the most likely nutritional cause of poor reproductive performance, deficiency of other specific nutrients, particularly the vitamins and minerals, has been shown to affect fertility. Although the mechanisms involved are being elucidated, there is still much conflicting information on the relationship between nutrition and reproduction. It is, however, likely that energy balance is a prime factor determining the length of the acyclic period in dairy cows, and even in suckled beef cows long postpartum acyclic periods can be reduced by the provision of increased dietary energy. The individual interactions of nutritional status with ovarian activity, oestrous behaviour and fertility at mating still require more detailed study.

Season
In the temperate latitudes seasonal variations in conception rates and a longer interval between parturition and first oestrus in the winter and early spring have long been reported. Furthermore, spring-calving beef and dairy cows have been reported to undergo longer periods between calving and first ovulation than autumn calvers. Many wild species of Bovidae are seasonal breeders, changes in daily photoperiod being the cue for onset or termination of ovarian activity. Photoperiod might play some role in seasonality of reproductive activity in the cow, there is a negative correlation between daily photoperiod during late pregnancy and the onset of ovarian cycles postpartum. It is thought that a vestigial sensitivity to photoperiod may be present in the domestic cow and that in feral cattle this pattern would predispose towards calving during the late spring to early summer, the optimal time for food supply. Season of birth has also been shown to affect age at first oestrus in heifers, with those born in spring reaching puberty approximately two months before those born in autumn. In hotter climates, seasonal anoestrus, short oestrous periods, poor conception rates and increased embryo mortality occur in both Bos taurus and Bos
**Indicus** during the hot season. Summer infertility due to heat stress is a well-recognized phenomenon in such areas, although embryo mortality may be the main specific problem. However, prolonged anoestrus, often encountered when *Bos taurus* cattle are introduced into tropical environments, occurs mainly as a result of malnutrition rather than as a direct result of high temperatures.

**Uterine effects**
Involution of the uterus is necessary before the cow can conceive again. The uteri of primiparous cows usually involute more rapidly than those of multiparous ones and suckling appears to stimulate involution, this usually being completed by about day 30 in the suckling cow. A correlation between the duration of elevated plasma concentrations of the PGF2a metabolite 13,14-dihydro-15 keto PGF2a (PGFM) and time for completion of uterine involution. Furthermore, it has been shown that PGFM levels invariably return to baseline before any rise in progesterone occurs, suggesting that uterine involution is usually more or less complete before the first postpartum ovulation occurs. Dystocia may result in both long anoestrous periods postpartum and a decreased conception rate. Retained placenta may also result in longer postpartum acyclic periods. It is possible that these conditions may result in an inhibition of uterine involution thereby delaying ovulation. Other evidence suggests that lack of uterine involution predisposes to prolonged luteal function following the first postpartum ovulation. The uterus has more specific effects on postpartum ovarian activity. Dominant follicles are less likely to be selected on the ovary ipsilateral to the previously pregnant uterine horn, but, if they are, the time to subsequent conception is reduced. Bacterial contamination of the uterus after parturition is almost inevitable and it is now thought that a high level of bacterial contamination can depress follicle selection, the effect usually being greater in the previously pregnant horn. In summary, a variety of factors affect the onset of ovarian cycles in the postpartum period. Nutritional status, especially energy balance, seems to be the overriding factor, but suckling, milk yield and season can also be important. In many studies and in the practical situation, the effects of two or more of these factors may have been confounded. This has made it difficult to determine their relative importance in predicting the acyclic period. In many cases, especially in Third World conditions, the situation is further complicated by the fact that different breeds, within *Bos taurus*, *Bos indicus* and their crosses, vary in their tendency to postpartum acyclicity and in their response to specific factors affecting this. In practical terms it is apparent that, provided oestrus detection rates are satisfactory, then the acyclic period is unlikely to result in calving intervals greater than 365 days unless it is itself in excess of 50–60 days.

**Induction of ovulation in postpartum cows**
We have shown how the inhibitory effects of the environmental factors discussed above on the reproductive system are mediated by the endocrine system and probably via a common final mechanism. The availability of hormonal therapy that would overcome acyclicity or true anoestrus, irrespective of primary cause, would be of great advantage, particularly in beef cattle where husbandry and nutrition are often only marginally adequate. In the past many such treatments have been based on empirical approaches with little regard to the underlying reproductive physiology. However, detailed knowledge of the pattern of hormone release is essential in order to understand the mechanisms controlling ovulation and ovarian cycles so that appropriate treatments can be used.

**There are four main areas of activity:**
1- The tubular genital tract, especially the uterus, is shrinking and atrophying due to tissue loss, thus reversing the hypertrophy that occurs in response to the stimulus of pregnancy. Myometrial contractions, which continue for several days after parturition, aid this process and help in the voiding of fluids and tissue debris; this is normally referred to as involution.

2- The structure of the endometrium and deeper layers of the uterine wall is restored.

3- There is a resumption of ovarian function in polyoestrous species and a return to cyclical activity.

4- Bacterial contamination of the uterine lumen is eliminated.

**Uterine Involution:**

The reduction in the size of the genital tract is called involution; it occurs in a decreasing logarithmic scale, the greatest change occurring during the first few days after calving. Uterine contractions continue for several days, although decreasing in regularity, frequency, amplitude and duration. The atrophy of the myofibrils is shown by their reduction in size from 750 to 400 μm on the first day to less than 200 μm over the next few days. The diameter of the previously gravid horn was halved by 5 days and its length halved by 15 days. Reduction in the rate of involution between 4 and 9 days postpartum, with a period of accelerated change from days 10 to 14 and a gradual decrease thereafter. Associated with this phase of rapid involution is uterine discharge. The whole of the uterus is usually palpable per rectum by 8 and 10 days postpartum in primipara and pluripara, respectively. The speed of involution of the non-gravid horn is more variable than that of the previously gravid horn, which depends upon its degree of involvement in placentation.

There is some dispute about when uterine involution is complete; the differences are probably only subjective. In six studies reported in dairy cattle the time taken for complete involution ranged from 26.0 to 52.0 days, whilst in three studies in beef cattle it was 37.7–56.0 days. The changes after 20–25 days are generally almost imperceptible. The cervix constricts rapidly postpartum; within 10–12 hours of a normal calving it becomes almost impossible to insert a hand through it into the uterus, and by 96 hours it will admit just two fingers. The cervix also undergoes atrophy and shrinkage due to the elimination of fluid and the reduction in collagen and smooth muscle; the mean external diameter was 15 cm at 2 days postpartum, 9–11 cm at 10 days, 7–8 cm at 30 days and 5–6 cm at 60 days. A useful guide that involution is occurring normally is to compare the diameter of the previously gravid horn with that of the cervix, since at about 25 days postpartum the latter starts to exceed the former. Prostaglandins may have a role in controlling uterine involution, although the postpartum rise in the metabolite of PGF2α may be a reflection of the process of involution rather than the cause. A positive correlation between PGFM concentrations in the peripheral circulation and the diameter of the uterine horn. Using exogenous PGF2α twice daily for 10 days starting from 3 days postpartum, uterine involution has been accelerated by 6–13 days; however, the number of animals was small and the frequency and duration of the treatment regimen were very atypical of the normal situation. Since the increase in the uterine mass during pregnancy is due to a combination of increases in both collagen and smooth muscle, then involution must be associated with a reduction of these tissues. Exogenous hormones such as oestrogens, PGF2α, and long acting oxytocin analogues do not influence the rate of involution.

**Restoration of the endometrium**
Although placentation in the cow is considered to be of a non-deciduous type it is well recognised that during the first 7–10 days after calving there is usually a noticeable loss of fluid and tissue debris. This is sometimes referred to by the herdsman as the ‘second cleansing’ or ‘secundus’. In human gynaecology the postpartum vaginal discharge is referred to as lochia. The presence of such a discharge in cows is normal, although sometimes individuals will mistake it for an abnormal discharge due to uterine infection and request treatment. The lochial discharge is usually yellowish brown or reddish brown; the volume voided varies greatly from individual to individual.

Pluripara can void up to a total of 2000 ml, although it is more usually about 1000 ml. In primipara it is rarely more than 500 ml and in some animals it is occasionally nil, owing to the complete absorption of the lochia. The greatest flow of lochia occurs during the first 2–3 days; by 8 days it is reduced, and by 14–18 days postpartum it has virtually disappeared. At about 9 days it is frequently bloodstained, whilst before it ceases it becomes lighter in colour and almost ‘lymph-like’. Normal lochial discharge does not have an unpleasant odour. The lochia are derived from the remains of fetal fluids, blood from the ruptured umbilical vessels, and shreds of fetal membranes, but mainly from the sloughed surfaces of the uterine caruncles. The slough occurs following degenerative changes and necrosis of the superficial layers. After the shedding of the allantochorion the caruncle is about 70 mm long, 35 mm wide and 25 mm thick. The endometrial crypts frequently contain remnants of the chorionic villi which were detached from the rest of the allantochorion at the time of placental separation. Within the first 48 hours postpartum there is evidence of early necrotic changes in the septal mass of the caruncle; the caruncular blood vessels become rapidly constricted and are nearly occluded. At 5 days the necrosis has proceeded rapidly, so that the <i>stratum compactum</i> is now covered by a leucocyte-laden necrotic layer. Some of this necrotic material starts to slough and contributes to the lochia. Small blood vessels, mainly arterioles, then protrude from the surface of the caruncle, from which there is oozing of blood, causing a red coloration of the lochia. By 10 days, most of the necrotic caruncular tissue has sloughed and undergone some degree of liquefaction and by 15 days postpartum sloughing is complete, leaving only stubs of blood vessels protruding from the exposed <i>stratum compactum</i>. This eventually becomes smooth by 19 days, owing to the disappearance of the vessels. Regeneration of the epithelium of the endometrium occurs immediately after parturition in those areas which were not seriously damaged and is complete in the intercaruncular areas by 8 days. Complete re-epithelialisation of the caruncle, which is largely derived from centripetal growth of cells from the surrounding uterine glands, is complete from 25 days onwards,
although the stage at which complete healing occurs is variable. Whilst these changes are taking place the caruncles are becoming smaller, so that at 40–60 days they consist of small protrusions 4–8 mm in diameter and 4–6 mm high. They also differ from those of nullipara because they are larger and have melanin pigmentation and a more vascular base.

**Resumption of ovarian function:**

Anovulatory follicular waves occur periodically during pregnancy, with the emergence of follicles of up to a maximum of 6 mm in diameter. However, because of the prolonged period of inhibition during pregnancy, due to the continuous negative feedback effect of progesterone secreted by the corpus luteum and placenta, the pituitary is refractory postpartum, as demonstrated by a lack of response to the administration of gonadotrophin releasing hormone (GnRH). This eventually recovers with time. As a result of the absence or low output of gonadotrophins, the ovary is relatively quiescent and the cow is in the anoestrous phase, which may be prolonged in suckler and high-yielding cows. However, during this postpartum phase the ovaries frequently contain numerous large anovulatory follicles which quickly become atretic; these are sometimes incorrectly diagnosed as cysts. In the immediate postpartum period both oestradiol and progesterone are low. The anterior pituitary is capable of releasing FSH during the first few days postpartum, so that with the sporadic release of endogenous GnRH there is a gradual and sustained rise in plasma FSH. After about 7–10 days, this is sufficient to result in the emergence of the first follicular wave; this occurs at about 4 days in dairy cattle, and 10 days in beef cattle. The ability of the pituitary to release luteinising hormone (LH) is much slower, for although the early release of GnRH causes some rise in LH, it quickly returns to basal levels. If a very large dose of endogenous GnRH is given within 10 days of calving there is no release of LH. If standard doses of GnRH are given at 10 and 16 days postpartum in milked cows, then LH rises; however, in unmanicured suckler beef cows 20 days had to elapse and in spring-calved suckler beef cows 30 days had to elapse. Further evidence of the refractory state of the hypothalamus and pituitary gland has been demonstrated by the failure of a 1 mg dose of oestradiol benzoate to elicit a surge of LH at 0–5 days postpartum; a response was obtained by 10 days which was increased by 25 days. A dominant follicle may emerge from the first follicular wave, but ovulation will occur only if the dominant follicle produces enough oestradiol to stimulate adequate LH secretion in the form of one pulse per hour; if this occurs, then there is a first ovulation at 21 days in dairy and 31 days in beef cattle. Insulin growth factor (IGF-1) is also involved in the early onset of Folliculogenesis and ovulation, by stimulating follicular granulosa cell aromatase activity and oestradiol synthesis. After ovulation, there is a luteal phase which may be of normal length with a return to oestrus after 18–24 days, or it may be much shorter, 14 days or less; the latter occurred in 25% of dairy but in 78% of beef cattle. These short luteal phases probably arise because of inadequate preovulatory development of the follicle so that it either becomes luteinised in the absence of ovulation, or more likely luteinisation of the CL is inadequate. These short luteal phases are more prevalent the earlier the return of normal ovarian activity, i.e. 100% at 0–5 days, 60% at 10–15 days and 10% at 25–30 days postpartum. However, it is now accepted that the first sign of oestrus is not always a true reflection of the onset of cyclical activity. This is because the CNS requires prior exposure to progesterone to elicit behavioral signs; a similar phenomenon occurs in ewes at the beginning of the breeding season. Using continuous time-lapse video recording of herds, 50, 94 and 100% of cows were identified in oestrus at the first, second and third postpartum ovulations; however,
with daily observations the frequencies of detected oestrus were 16, 43 and 57%, respectively. The uterus exerts an influence since it has been known for some time that the majority of ovulations postpartum occur in the ovary contralateral to the previously gravid horn; the effect is less, the later ovulation occurs. It has also been shown that prostaglandin metabolite (PGFM) usually returns to normal levels before the first postpartum ovulation. Similarly, the ovariouterine axis exerts an inhibitory effect on pituitary LH secretion during the early postpartum period; experimental hysterectomy results in a rapid increase in plasma gonadotrophin concentrations. The adrenal cortex plays an important role in influencing the return to oestrus postpartum. Adrenocorticotrophic hormone (ACTH) and corticosteroid administration suppress the secretion of LH. Stimulation of the teat and milk removal cause a rise in glucocorticoids. Suckling, which is known to delay the return of cyclical ovarian activity, may exert its effect by modifying the tonic release of GnRH and LH by the release of opioid peptides. The role of prolactin is equivocal, for although bromocriptine treatment during lactation had little or no effect on LH release in cows, there appears to be a reciprocal relationship between the hypothalamic control of LH release and prolactin release. Opioid agonists increase LH and decrease prolactin secretion; the effects of the agonists are the reverse. The mammary gland has also been shown to have an endocrine role.

**Elimination of bacterial contamination:**

At calving, and immediately postpartum, the vulva is relaxed and the cervix is dilated thus allowing bacteria to gain entry into the vagina, and thereafter the uterus. A wide range of bacteria may be isolated from the uterine lumen; a 33 different species, those most frequently isolated being Arcanobacterium (Actinomyces Corynebacterium) pyogenes, Escherichia coli, streptococci and staphylococci. In all studies there is a decrease with time in the percentage of uteri from which bacteria are isolated. Blood, cell debris and sloughed caruncular tissue provide an ideal medium for bacterial growth; however, in most cases the bacteria do not colonise the uterus to produce a metritis/endometritis. The main mechanism involved in the elimination of the bacteria is phagocytosis by migrating leucocytes; however, persistence of uterine contractions, sloughing of caruncular tissue and uterine secretions all assist in the physical expulsion of the bacteria. Early return to cyclical activity is probably important since the oestrogen dominated uterus is more resistant to infection. However, there is evidence that in some cases early return to oestrus may be disadvantageous, in that if the bacteria are not eliminated at the first oestrus then the cow enters the first luteal phase where progesterone is the dominant hormone.

**Factors influencing the puerperium**

1. **Uterine involution**
   - **Age.** Most observers have found that involution is more rapid in primipara than pluripara.
   - **Season of year.** If there is any influence, involution is probably most rapid in spring and summer.
   - **Suckling vs. milking.** Results are contradictory; it may be a breed influence on the effect of time to return of cyclical ovarian activity.
   - **Climate.** There is evidence that heat stress can accelerate and inhibit the speed of involution.
   - **Periparturient abnormalities.** Dystocia, retained placenta, hypocalcaemia, ketosis, twin calves and metritis delay involution. Periparturient problems cause an overall delay in the completion of this process of 5–8 days.
   - **Delayed return to cyclical ovarian activity.** This inhibits involution.
2-Restoration of the endometrium.
There is little related documented evidence; however, retained fetal membranes and metritis inhibit healing, whilst ovarian rebound to cyclical activity may have an influence.

- **Periparturient abnormalities.** A number of authors have shown that a whole range of periparturient problems delay ovarian rebound.
- **Milk yield.** There is much contradictory evidence on the influence of current milk yield; some authors have demonstrated an effect of the lactation preceding calving. It is frequently difficult to differentiate the influence of nutrition and milk yield.
- **Nutrition.** In both beef suckler and dairy cows, inadequate feeding, especially of energy, during the dry period and after calving inhibits ovarian rebound. This will usually be shown as poor body condition score. Ovulation of the dominant follicle will occur after 3.2 ± 0.2, or 10.6 ± 1.2, follicular waves in beef cows in good and poor body condition score, respectively. The effect of nutrition on ovarian function is likely to be mediated by insulin and IGFs.
- **Breed.** Whilst it has been known for some time that there is a longer delay in beef compared with dairy cows there is evidence of a breed effect within the two groups especially in the former.
- **Parity.** Most observers have recorded a delay in primipara compared with pluripara – up to the fourth lactation. Conflicting opinions have probably arisen because of the problems of separating the influences of nutritional status, milk yield and weight loss.
- **Season of the year.** There is good evidence that photoperiod has an effect. This has been shown by experimentally subjecting heifers to continuous darkness, which inhibited the return of cyclical activity. Suckler cows that calved between February and April were acyclic significantly longer than those that calved between August and December. By stimulating the effects of short day length using exogenous melatonin it has been possible to delay the return to oestrus and ovulation in postpartum beef cows.
- **Climate.** Cows in tropical climates show a delay compared with those in temperate zones.
- **Suckling intensity and milking frequency.** The greater the frequency of milking and the intensity of suckling (number of calves), as well as calf presence, the longer the period of acyclicity. This can be reversed in beef suckler cows by restricting the access of the calf to suckle from 30 days postpartum.

3-Elimination of bacterial contamination.

- **Magnitude of bacterial contamination.** A massive bacterial flora may overwhelm natural defence mechanisms.
- **Nature of bacterial flora.** Many obligate Gram-negative anaerobes, such as *Fusobacterium necrophorum* and *Bacteroides* spp., exhibit synergy with Gram-positive aerobic contaminants.
- **Delayed uterine involution.**
- **Retained placenta.**
- **Calving trauma to the uterus.**
- **Return of cyclical ovarian activity.** There is contradictory evidence since, with an early return to oestrus, there is an early oestrogen peak which should assist in the elimination of the bacteria. However, if the level of contamination is such
that a significant bacterial flora persists after the first oestrus the subsequent luteal phase may allow the bacteria to proliferate.

Post-partum Events in the mare

The puerperium is shorter in the mare than in the cow, with rapid involution and relatively good conception rates at the first postpartum oestrus. The mare is unusual compared with many other domestic species in that uterine involution is extremely rapid, and there is a return to fertile oestrus within a few weeks of parturition. A new pregnancy may be established very early in the post-partum period. In pony mares it is usually possible to identify the outline of the uterine body and horns by rectal palpation at about 12 hours postpartum; in thoroughbreds it is longer. Lochial discharge is relatively slight in most mares and usually ceases by 24–48 hours after foaling, although in a few cases it can persist for up to a week. The uterine horns shrink rapidly, reaching their pregravid size by day 32. Although the previously non-gravid horn was initially smaller, it shrinks at a slower rate. The cervix remains slightly dilated until after the first oestrus.

Uterine involution

Myometrial contractility increases after parturition and is greater under the influence of oestrogen when the mare returns to oestrus. Uterine involution is amazingly rapid after normal parturition.

- Histologically, there is no disruption of the endometrium at parturition.
- The uterine horn which housed the fetus will remain larger than the other horn.
- It may be difficult to define when involution is complete, i.e. when the previously-pregnant horn is no longer identifiable by palpation.
- The cervix remains relaxed until after the foal heat ovulation.
- New pregnancies almost invariably establish in the smaller uterine horn (previously non-gravid).
- There is uterine tone during involution and after the foal heat. This may make early manual diagnosis of pregnancy difficult; enlargement at the base of the previously-pregnant horn may be mistaken for an 18–28 day conceptus.

Assessment of uterine involution

- Transrectal palpation may allow an estimation of the size of the uterus.
- Vaginal or speculum examination per vaginam may allow inspection of the cervix and of any cervical discharge.
- Transrectal ultrasound examination allows accurate imaging of the uterus. The uterine dimensions, thickness of the uterine wall, presence of luminal fluid, and presence of luminal debris can easily be assessed.

Post-partum uterine infection

- Bacteria may enter the mare’s uterus post partum.
- This risk can be reduced by suturing or clipping the dorsal vulva closed immediately after delivery.
- The post-partum uterine flora is usually dominated initially by coliforms, and later by b-haemolytic streptococci.
- Post-partum colonisation of the uterus by bacteria is a normal event, and it should be expected.
- After normal parturition, most mares eliminate bacteria before the foal heat.
- For the first few days after parturition there is a moderate volume of vulval discharge (lochial fluid expelled from the uterus).
- Very little discharge is normally seen after the first few days post partum.
Assessment of post-partum infection
- Post-partum infection of any significance is associated with uterine luminal fluid that can be detected using ultrasound imaging.
- Persistent vulval (cervical) discharge is indicative of infection.
- Uterine swabs may be investigated for the presence of bacteria and/or neutrophils.

Post-partum cyclicity
- Most mares usually return to oestrus approximately 5–9 days after parturition.
- This oestrus is generally known as the ‘foal heat’, since the foal often develops a physiological scour at this heat.
- Diarrhoea in the foal makes the identification of oestrus in the mare more obvious.
- Post-partum oestrus may not occur for a variety of reasons:
  - The mare foaled early in the year, or in adverse climatic conditions, in which case she may enter an effective seasonal anoestrus. In these cases cyclical activity will return when climatic conditions improve, the day length increases and the mare’s plane of nutrition is adequate.
  - The mare has normal endocrinological changes but is reluctant to exhibit oestrus due to maternal instinct. This is termed silent oestrus, and is related to the mare being protective of the foal. Silent oestrus in this instance may be prevented by teasing the mare whilst either holding the foal securely near to the head of the mare, or confining it to a loose box away from the mare; the mare may need to have a twitch applied.
- Following the first post-partum oestrus the mare may also fail to cycle for a variety of reasons:
  - The mare continues to have silent oestrus;
  - The mare enters prolonged dioestrus (the corpus luteum persists);
  - The mare may enter anoestrus, although in this case it is more likely that the mare did not ovulate at the first post-partum oestrus.
- Fertility at the first post-partum oestrus has been recorded as being 5–10% lower than at subsequent oestruses. This may be related to a failure of the uterus to become completely involuted. When ovulation occurs more than ten days after parturition, the pregnancy rate is higher than when ovulation occurs before day ten.
- It may be possible to delay the ovulation at the foal heat by giving progesterone for one week commencing the day after foaling. Such treatment usually ensures that ovulation occurs more than ten days after foaling. The effect of exogenous progesterone on uterine involution is not known.
- ‘Short-cycling’ the mare after the foal heat is a common method of ensuring breeding quickly after foaling, but enabling normal involution to be completed. Prostaglandin is administered seven days after the end of the foal heat and the mare is bred at the induced oestrus.
- Opinion as to whether mares should be bred at the foal heat is divided.

When to breed at foal heat
Don’t use foal heat if:
- Involution is physically poor (uterine fluid, thickened uterine wall detected with ultrasound);
- The mare has a discharge or a positive culture (or neutrophils) at mating time;
- The mare had dystocia or retained fetal membranes;
- The mare foaled early and an even earlier foal is not required;
- If the mare has ovulated by the eighth day post partum or earlier she is unlikely to conceive;
- The mare has concomitant damage to the cervix, vagina or perineum;
• Semen quality is poor or a small volume of semen is to be used (e.g. artificial insemination with preserved semen).

**Do use foal heat if:**
- The mare foaled late in season;
- Post-partum events seem normal;
- Involution is adequate (assessed by palpation and ultrasound examination);
- The mare is known to have aberrant cycles after the foal heat.

**Advantages and disadvantages of using the foal heat**

**Advantages of using the foal heat:**
- It is easily recognisable because of foal diarrhoea and the record of recent foaling;
- It avoids the confusion of erratic cyclic behaviour thereafter;
- It may be last chance of conception for late foalers.

**Disadvantages of using foal heat:**
- Conception rate is lower than for other heats;
- Subsequent pregnancy loss may be higher;
- Mating a mare with a diseased endometrium may prejudice against conception at a later heat or even cause permanent damage, especially after the first foal.

**Ewe and doe (nanny) goat**

The puerperium in both these species is very similar to that in the cow, being typical of ruminants in general. The main difference is that, since they are both seasonal breeders, parturition is followed by a period of anoestrus. There is little information available for the doe so that the changes that are described relate only to the ewe, although it is unlikely that there will be major differences. **Involution** There is rapid shrinkage and contraction of the uterus, particularly during the third to 10th days postpartum, as determined by measurements of uterine weight and length, diameter of uterine body and previously gravid horn. According to these measurements, involution is complete by 20–25 days. Using sequential radiography and radio-opaque markers, uterine involution has been shown to be complete by about 28 days in suckling ewes, although an unexplained increase in uterine dimensions has been reported at 42 days. Involution in the ewe is also due to collagen breakdown, since although tissue collagen concentrations remain fairly constant with advancing pregnancy, there is a 7- to 8-fold increase in uterine mass; the reduction in size can only be a reversal of this process.

**Restoration of the endometrium**

As in the cow, there are profound changes in the structure of the caruncles with degeneration of the surface, necrosis, sloughing and subsequent regeneration of the superficial layers of the endometrium. There is evidence, determined by the slaughter of animals 3 days before the expected date of lambing, of prepartum hyaline degenerative changes. This occurs in the connective tissue at the base of, and adjacent to, the endometrial crypts and also involves both directly and indirectly the walls of the arteries and veins, thus reducing their lumens; the fetal villi are unaffected. After dehiscence and separation of the placenta there is further hyaline degeneration of caruncular tissue, which results in constriction of the blood vessels at the base of the maternal crypts. There is necrosis of the surface layer of the caruncle so that at about 4 days postpartum the most superficial layers are undergoing autolysis and liquefaction, which are responsible for the dark reddish brown or black coloration of the lochial discharge at this time. By 16 days postpartum, necrosis of the whole superficial part of the caruncle has occurred with, in most cases, separation of the brown necrotic plaque so that it is lying free in the uterine lumen. The caruncles now have a clean, glistening surface, and the process of regeneration is completed by the
re-epithelialisation of the caruncles by about 28 days. The quantity of lochia voided is variable. Initially it arises from blood, fetal fluids and placental debris but as the puerperium proceeds the liquefied, sloughed caruncular tissue contributes to it.

Return of cyclical activity (ovarian rebound)
Although in temperate climates ewes normally become anoestrus after lambing there are numerous reports of ovarian activity occurring within a few days to 2 weeks postpartum. Follicular growth is common but ovulation is unusual and when it does occur it is usually associated with a silent heat. Failure of follicular maturation and ovulation is probably due to inadequate release of LH as a result of a deficiency in GnRH synthesis and secretion. As a result, basal LH levels and the pulse frequency of episodic LH secretion are inadequate to stimulate normal ovarian function. It is possible that the time of the year when the ewes lamb has a profound effect, with those that lamb early and within the normal breeding season being more likely to have normal ovarian rebound.

Elimination of bacterial contamination
Although it would have been expected that similar events to those previously described for the cow and mare would occur, the author was unable to isolate bacteria from uterine swabs obtained from 10 ewes, 1–14 days postpartum, at surgical hysterotomy. More recently, using sequential transcervical swabbing of 13 ewes during the first week postpartum, bacteria were isolated from four ewes; thus in the other nine ewes the uterus was sterile.
Dystocia

Dystocia means difficult birth; the corresponding Greek word for normal birth is eutocia. The diagnosis of dystocia is frequently based on a high degree of subjectivity, since there are situations that one person will consider to be normal, but another will consider difficult. For this reason, some of the data on the incidence, causes or efficacy of treatment of dystocia are not very reliable, although there are many circumstances when distinguishing between the two will present no difficulty. The diagnosis and treatment of dystocia constitute a large and important part of the science of obstetrics, and require a good understanding of normal parturition, sensitivity to the welfare of both dam and offspring, and good and sensitive practical competences. In addition, veterinarians must always try to prevent dystocia where possible, by the application of sensible sire and dam selection, and good husbandry and health care.

CAUSES OF DYSTOCIA
Obstetricians have usually regarded dystocia as being either maternal or fetal in origin.

Each case of dystocia is a clinical problem that may be solved if a correct procedure is followed. A correct diagnosis is the basis of sound obstetric practice.

**HISTORY OF THE CASE**

Therefore, before proceeding to examine the animal, a brief history of the case should, whenever possible, be obtained. Much of it will be the outcome of questioning the owner or attendant, but many points will also be elicited from personal observation of the animal.

- Has full term arrived or is delivery premature?
- Is the animal a primigravida or multigravida?
- What is her previous breeding history?
- What has been the general management during pregnancy?
- When did straining begin? What was its nature – slight and intermittent or frequent and forceful?
- Has straining ceased?
● Has a water-bag appeared and, if so, when was it first seen?
● Has there been any escape of fluid?
● Have any parts of the fetus appeared at the vulva?
● Has an examination been made and has assistance been attempted? If so, what was its nature?
● In the case of the multiparous species, have any young been born, naturally or otherwise, and if so, when? Were they alive at birth?
● Is the animal still taking food?
● In the case of the bitch and cat, has there been vomiting?

By a consideration of the answers to these and similar questions, it is possible to form a fairly accurate idea of the case to be dealt with. The inference to be drawn from many of them is obvious, but there are several points associated with them which merit discussion. The greatest attention will be paid to the duration of labour. Calculating the time of onset of first stage is often difficult because, the signs are sometimes very vague and indistinct. However, the onset of vigorous and frequent straining, together with the appearance of the amnion, the expulsion of fetal fluids, or the appearance of a fetal extremity, indicates the onset of the second stage of labour, and parturition should proceed normally. If several hours have elapsed since its onset, it is reasonably certain that obstructive dystocia exists. Nevertheless, it is probable in all species except the mare that the fetus or fetuses are still living, unless the signs have not been observed and their significance understood. In the primigravida, particularly the heifer and the bitch, it is often found that the cause of the dystocia is relatively simple, such as slight fetomternal disproportion, and the application of a little assistance is all that is required. In the mare, the normal course of delivery is so rapid, and separation of the placenta occurs so quickly once the second stage has commenced, that any delay generally results in the death of the foal due to anoxia.

GENERAL EXAMINATION OF THE ANIMAL

The animal’s physical and general condition should be noted. If recumbent, is she merely resting or is she exhausted or suffering from a metabolic disease? Body temperature and pulse rate should be noted and the significance of abnormalities considered. Particular attention should be paid to the vulva. Parts of a fetus may be protruding and it may be possible to assess the nature of the dystocia from these. Are exposed fetal parts moist or dry? Such evidence serves not only as a guide to the duration of the condition, but also to the effort that will be necessary to correct it. Should parts of the amnion protrude, what is their condition? Are they moist and glistening and is fluid caught up in their folds? If so, their exposure is recent and the case is an early one. If, however, the membranes are dry and dark in colour, it may be taken that the case is protracted. Maybe nothing protrudes from the vulva, in which case particular attention should be paid to the nature of the discharge. Fresh blood, especially if profuse, generally indicates recent injury to the birth canal. A dark brown fetid discharge indicates a grossly delayed case. Where it is clear from the evidence already obtained that the fetus is dead and the uterus grossly infected, the desirability of inducing epidural anaesthesia before proceeding to a vaginal examination should be considered. In this way the risk of infecting the neural canal should spinal anaesthesia later be found to be necessary is reduced. When dealing with the bitch and cat, the degree of abdominal distension should be observed, for it may be possible to make an estimate of the number of fetuses which occupy the
uterus. The onset of vomiting, together with a great increase in thirst, should be regarded as grave signs in the bitch.

Uterine inertia

Primary uterine inertia

Etiology  The most common cause is hypocalcemia, with the cow showing signs of milk fever as calving is about to begin. Other causes include distension of the uterus caused by hydrops uteri, general debility with reduced tone and responsiveness in the myometrium, and environmental disturbance. The presence of twins may cause such stretching of the myometrium that effective contractions cannot occur. Primary uterine inertia has also been seen in overweight beef cows that fail to go into labor. Some such animals may be mildly ketotic and possibly on the verge of pregnancy toxemia.

Clinical signs  Preparations for birth begin but do not continue into second-stage labor. The fetus is normally in the correct presentation, position, and posture. The cervix is dilated or easily dilatable with manual pressure but there is no evidence of uterine contractions. The fetal membranes, especially the amnion, are often still intact. In cases of hypocalcemia the patient will be dull, reluctant or unable to rise, and have a low temperature, dilated pupils, and reduced rumenal activity. The head is turned back to the flank and, if untreated, the cow may become comatose with death ensuing. In cases of hydrops uteri there will probably have been a history during pregnancy of increasing abdominal size and debility. If accessible the uterine wall is found to lack muscle tone when palpated.

Treatment  If hypocalcemia is suspected, intravenous treatment with 400 mL of either 20% or 40% calcium borogluconate solution should be given. A further 400 mL of the drug is given by subcutaneous injection. If the farm has a history of coincidental magnesium deficiency, an injection of 400 mL calcium:magnesium:phosphorus:dextrose solution should be given intravenously. In many cases, parturition will resume but delivery should be assisted with moderate traction, as it
should be in cases of uterine inertia resulting from other causes. Failure to deliver the calf promptly may result in its death if placental separation occurs. Following removal of the fetus, an injection of 20 IU oxytocin should be given by intramuscular injection to encourage uterine involution and placental expulsion.

**Secondary uterine inertia**

**Etiology** The consequence of another cause of dystocia, for example fetal maldispersion, with resultant tiring of the myometrium.

**Clinical signs** The uterine wall is felt to be flabby and lacking in tone often after the fetus has been delivered.

**Treatment** The primary cause of dystocia is treated and the fetus delivered. Uterine involution is encouraged after delivery by injection of oxytocin as in primary uterine inertia.

**Premature birth**

May be accompanied by failure of normal uterine contractions and, if unobserved or early in gestation, by fetal death.

**Etiology** May be caused by any factors that compromise fetal life and/or placental function.

**Clinical signs** There may be an unexpected vaginal discharge during pregnancy. An abnormal and sometimes foul-smelling placenta may be visible or is passed by the patient. The fetus, often small and hairless, is palpable in the anterior vagina or uterus. If the fetus has been delivered and not observed, only placental remnants may be left in uterus.

**Treatment** The fetus and birth canal may both be very dry. The fetus is delivered by gentle traction applied by hand to its head and limbs after thoroughly lubricating all the structures involved.

All cases of premature birth in cattle (a pregnancy of less than 271 days of gestation) must be notified in the UK to the local Divisional Veterinary Manager (DVM) of the Department for Environment, Food and Rural Affairs (DEFRA). The DVM may require the fetus or its stomach contents, a vaginal swab, maternal milk and blood samples to be submitted to the Veterinary Laboratories Agency (VLA) and examined for evidence of brucellosis. Other infectious causes should also be investigated and for this a piece of placenta, including a cotyledon, may be of additional diagnostic value.

**Failure of abdominal expulsive forces**

**Etiology** The abdominal musculature - so important during the second stage of labor - is either incapable of contracting or it is too painful for the animal to strain. In very old cows, or those suffering from hydrops, the abdominal muscles may have been stretched beyond the capacity of their natural elasticity. Tears in the muscles occur in cases of ventral hernia and as a result attempts to strain are compromised, as they are in cases of rupture of the prepubic tendon (see Chapter 2). Painful conditions involving the abdomen, diaphragm, or chest such as traumatic reticulitis/pericarditis may cause voluntary inhibition of attempts to strain. Laryngeal and diaphragmatic damage are rare in adult cattle but anything that compromises closure of glottis to enable straining to occur such as a tracheotomy wound could also compromise birth.

**Clinical signs** Birth fails to occur despite the presence of normal preparatory signs and first-stage labor. Difficulty should be anticipated following recognition of the primary problem. Vaginal examination reveals a dilated cervix with the fetus in normal presentation at the pelvic inlet. In cases of ventral hernia the fetus may be only just palpable or even beyond reach. Its position can be ascertained by external ballottement.

**Treatment** In cases of abdominal distension the fetus is delivered manually. If beyond reach it may be raised by assistants lifting the abdominal floor externally and is also aided by the patient lying down. In cases of diagnosed traumatic reticulitis or pericarditis where maternal health is deteriorating, or in cases of laryngeal or diaphragmatic disease, an elective cesarean should be considered.

**Uterine rupture**

**Etiology** Tearing of the uterus may occur as a result of traumatic injury to the cow, for example following collision with a vehicle. It may also occasionally occur spontaneously through an unsuspected weak point in the uterine wall. The fate of the fetus in such cases depends on whether it passes into the peritoneal cavity and the degree of compromise sustained by the fetal membranes. Small tears may be symptomless and the fetus remains in the uterus, where it develops normally and is born without difficulty. Larger tears may allow passage of the fetus into the peritoneal cavity. Maternal death may follow rupture with severe uterine hemorrhage. In cases where the placenta is compressed and
Torsion of the uterus during pregnancy

This a rare condition seen much less frequently than torsion of the uterus as a cause of dystocia at term (see below).

**Etiology** Unknown, but possibly associated with uterine instability and episodes of excited exercise.

**Clinical signs** The condition has been reported in animals from mid-pregnancy onwards. Affected animals may show signs of discomfort, some straining, and the tail head may be raised. Death may occur in untreated cases. The torsion is palpable on rectal examination as a rope-like structure involving the anterior vagina, cervix, and uterine body. The uterus may feel tenser than normal.

**Treatment** Surgical correction is necessary in most cases. The uterus is approached by a left flank laparotomy. The uterus (which may have some vascular compromise and is fragile) is carefully untwisted. Antibiotic and non-steroidal anti-inflammatory therapy is provided. The fetus and placenta can be monitored after treatment by ultrasonographic scan. Separation of the placenta from the endometrium and abortion may be complications.

Torsion of the uterus as a cause of dystocia at term

**Etiology** The bovine uterus has been said to be basically unstable for a number of reasons. These include: (1) the caudal parts of the uterus are attached to the lateral walls of the pelvis by the broad ligaments; (2) as pregnancy advances the cranial parts of the uterine horns lie on the abdominal floor with no stabilizing ligamentous attachment; (3) a single-calf pregnancy chiefly occupies one horn of the uterus, making the organ heavier and more bulky on one side than the other; (4) the instability may be increased by the cow lowering her front end first when lying down. Torsion occurs when the cow – or the fetus – makes a sudden movement causing the unstable uterus to rotate about its long axis. The bovine amnion is fused in places to the surrounding allantois, which is attached through the chorion to the uterine wall. If the fetus rotates
about its long axis in late gestation the uterus may be rotated with it. Reduced exercise may increase the incidence of torsion.

**Clinical signs** The first signs may be noted towards the end of first-stage labor, which is prolonged, and the cow may show signs of mild discomfort. The patient may adopt a ‘rocking-horse’ stance so that the dorsal surface of her spine is concave and the fore- and hindlimbs are held respectively further forward and backwards than normal. Torsion of the birth canal may cause one or both lips of the vulva to be pulled in. Vaginal examination reveals an abnormal disposition of the birth canal (Fig. 4.2). The hand cannot immediately be passed anteriorly towards the cervix. The vagina narrows conically and folds of vaginal mucosa may be felt going into an oblique spiral. The direction of the vaginal folds may indicate the direction of the torsion – either clockwise or ant clockwise.

If the torsion is less than 180° the obstetrician’s hand may be passed through the constriction to palpate the fetus. In such cases care must be taken to avoid mistakenly thinking a dead fetus is alive. When palpated through the twisted anterior vagina the fetus may appear to float away from the obstetrician’s hand and then spontaneously return as if alive. The cervix is normally dilated.

If the torsion is greater than 180° the birth canal may be totally occluded, with the vagina coming to a conical end with no recognizable cervix being palpable. Rectal examination will confirm the displacement, with the broad ligaments being abnormally palpable as taught bands in the caudal abdomen.

**Prognosis** This is quite good in cases that are recognized and dealt with promptly. In cases that have not been treated for some time after they occurred severe compromise of the blood supply to the uterus may occur. In such cases the calf may die and the uterine wall may become necrotic and friable. Uterine rupture may occur spontaneously or at attempted treatment by rolling, and peritonitis, toxemia, and death may occur. The possibility of unseen uterine damage should always be remembered in cases in which treatment has been delayed or which do not do well after treatment.

**Treatment** A number of methods are available:

*Rotation of the fetus and uterus per vaginam back into their correct position* This is possible if the obstetrician’s hand can pass into the uterus and touch the fetus and if fetal fluids remain within the uterus. The fetus is grasped by a convenient prominence such as the elbow, sternum, or thigh and is rocked from side to side before being pushed right over in the opposite direction to the torsion (Fig. 4.3). If the maneuver has been successful the torsion will have disappeared and the vagina regains its normal morphology.

*Rolling the cow* The principle of this method is to roll the cow around its uterus while that organ remains
still. Three assistants are required. The cow is cast on
the side to which the torsion is directed (Fig. 4.4). Thus
in an anticlockwise torsion she is cast on her left side.
The two forelegs and the two hind legs are tied together
and the head is restrained with a halter or head collar.
The cow is rolled sharply over onto her other (right)
side. The patency of the vagina is checked and if the
torsion persists the cow is gently rolled back onto her
other (left) side and the process is repeated. The cow
may have to be rolled two or three times before the
torsion is corrected.

The efficiency of rolling can be improved by putting
external pressure on the cow’s abdomen in an attempt
to ‘hold the uterus still’ while the cow’s body is rolled.
Manual pressure over the uterus can be used or a board
rested against the caudal abdomen and downward
pressure exerted by a person standing on it.

The calf should always be delivered by the obstetri-
cian as soon as the torsion has been corrected. The
cervix may close within 30 minutes of resolution of
the torsion preventing fetal delivery by the vaginal
route and necessitating cesarean section.

**Surgical correction** This may be necessary if fetal
rotation is impossible and rolling the cow is unsuccess-
ful. A left flank laparotomy is performed on the stand-
ing cow under local anesthesia (see also Chapter 11).
The uterus is located and the direction of the torsion
confirmed by palpating and examining the cervical
region. The uterine wall or a fetal limb within the
uterus is grasped firmly and an attempt made to rotate
the uterus back into its correct position.

Once the uterus is correctly in place the calf may be
delivered per vaginam or by cesarean section. If the
uterus cannot be rotated cesarean section must be per-
formed with the uterus in its abnormal position. Once
the fetus has been delivered the uterus can normally be
readily rotated into its correct position after repair of
the uterine wall. The condition of the uterine wall
should be carefully checked before abdominal closure.
If the uterus is discolored, its blood supply may have
been compromised. If normal color is not restored after
correction of the torsion the prospects for survival are
not good. Antibiotic cover and the administration of a
non-steroidal anti-inflammatory drug such as flunixin
may aid recovery and provide analgesia.
Evidence of fetal life

- Positive response to pedal withdrawal and palpebral reflexes.
- Response to pressure on the eyeball or pinching the nose or ear.
- Sucking reflex if fingers are placed in the calf’s mouth.
- Contraction of the anal sphincter when a finger is inserted.
- Spontaneous movement of the fetus, but excessive movements of the extremities or the tongue may indicate a developing hypoxia. Discoloration of the amniotic fluid with green meconium is a further sign of fetal compromise. Fetal breathing or bellowing

- Detection of fetal pulse in the metacarpus or metatarsus is occasionally possible but is also made difficult by maternal straining.

If sophisticated equipment is available the following may be tried but straining movements of the cow make recording difficult:

- Detection of heart beat by Doppler or B-mode ultrasonography or by detection of the fetal electrocardiograph. A long Doppler rectal probe can be inserted alongside a small fetus to rest against the chest wall giving clear signal of the heart rate.
- PO₂ and PCO₂ in the fetal blood can be measured if a blood-gas machine is available. A blood sample is taken from the metacarpal or metatarsal vein of the calf if the vessels are accessible. An immediate estimation of PO₂ and the fetal pulse rate can be obtained by means of pulse oximetry techniques. The attachment of a pulse oximeter to the ear or tongue of the calf during delivery is not always easy.
Evidence of fetal death
- Absence of positive signs of life (subject to the caveat concerning impacted fetuses).
- Blood staining of the amniotic fluid occurs 12 hours after fetal death and the development of corneal opacity commences; 72 hours after death collapse of the eyeball may begin – a useful observation if the fetal head is visible or palpable.
- Sterile autolysis of the fetus commences immediately after fetal death and if infection gains access via the cervix, putrefactive decay occurs with fetal emphysema and possibly the complication of septicemia and toxemia in the cow.
- Degeneration and separation of the placenta with loss of fetal fluids.
- If the fetal head is protruding from the vulva the ocular mucous membranes may be inspected. They should be pink in a healthy, well-oxygenated calf. Cyanosis indicates at least a degree of hypoxia. Extreme pallor of the membranes may suggest that the fetus is severely anoxic.

Any problem which interferes with the normal birth of a foal.

Presentation
The direction the foal is facing relative to the long axis of the mare; this can be:
- Anterior longitudinal, i.e. normal – the foal’s head is presented towards the mare’s vulva (preceded by the feet); a late pregnancy examination may often confirm this presentation;
- Posterior longitudinal, i.e. the foal is ‘back-to-front’ and the rump is presented first, preceded by the feet;
- Transverse – this implies that the foal lies at right angles to the mare’s spine, i.e. it occupies both uterine horns. In reality the foal cannot lie transversely across the mare’s abdomen and appears to be in a longitudinal presentation. Thus the uterus is distorted to accommodate this rare presentation.

Position
This describes the relationship between the foal’s back and the mare’s spine; normal birth is accomplished in the dorsal position, i.e. foal’s back uppermost.
- During later pregnancy the foal may lie on its side (lateral position) or back (ventral position) but rotates during late first- and early second-stage parturition – this may fail to occur during induced parturition.

Posture
The disposition of the extremities (neck and limbs), relative to the body.
- Essentially these are either extended (as the neck and forelimbs are in normal birth) or flexed.
• Hip flexion in posterior presentation results in ‘breech birth’.
• Flexion of the forelimbs may be unilateral or bilateral and involve any joint, and may occur in normal limbs or those with tendon contractions.
• Head and neck flexion only occur in anterior presentation and may be associated with ankylosis (fusion) of the cervical vertebrae (‘wry-neck’).
• Unilateral or bilateral flexion of the hind limbs, when the foal is in anterior presentation, results in the so-called ‘dog-sitting’ position which may be impossible to diagnose by palpation per vaginam.

Recognition of dystocia

The foal is normally born in anterior presentation, dorsal position and extended (head, neck and forelimbs) posture. Failure to observe the fluid-filled amnion (which may be visible only during contractions) at the vulva after five minutes of second-stage parturition indicates that vaginal examination is necessary and may reveal:
• Two feet (one anterior to the other) and a nose, i.e. normal birth – delay could be due to:
  _ Feto-maternal disproportion or fetal oversize; rare in mares except the smaller breeds of pony;
  _ Hydrocephalus impeding passage of the enlarged head through the cervix; rare;
  _ Slow relaxation of the cervix (for example after induction of parturition);
  _ Ineffectual straining; rare;
  _ Dorsal deviation of one or both feet – if unrecognised and not corrected this can cause recto-vaginal trauma;
  _ Slowness of the fetus to rotate into normal dorsal position – this is recognised by inability of the fetlocks to flex ventrally, but they will do so dorsally or laterally, and the limbs may be crossed.
• One foot and nose – carpal and/or shoulder flexion of one forelimb.
• Nose only – carpal and/or shoulder flexion of both forelimbs.
• Two limbs only; this could be:
  _ Head and neck flexion – carpi flex in a ventral direction unless position is also wrong;
  _ Posterior presentation with hind limbs extended; these flex in a dorsal position and the hocks should be palpable – recognition of the tail will help diagnosis.
• Nothing palpable in the vagina – this is serious and indicates:
  _ Transverse presentation – may recognise fetal abdomen in the uterus;
  _ Posterior presentation with bilateral hip flexion (breech);
  _ Anterior presentation with bilateral limb and head/neck flexion.
• Tough allantochorion identified – no fluid loss identified and the vagina is still relatively dry. Here the foal is being born in CAM and placenta separating.

NB: This must be distinguished from an unopened cervix; often an owner will misinterpret discomfort and grunting for second stage labour. • Very rarely, prolapse of the mare’s bladder causes dystocia.

Non-surgical treatment of dystocia

• Most mares are too concerned with foaling to worry about manipulation per vaginam.
• However, due to discomfort, the mare is disinclined to stand still.
• If the mare wants to lie down and roll, this can often be an advantage if it is proving difficult to manipulate the foal into a dorsal position.
• A bridle and/or twitch may be useful, but should not be relied upon.
• Tranquillisers may make early manipulation easier, but will reduce straining when this could be helpful.
• Epidural anaesthesia has the same advantage and disadvantage as tranquillisers – in addition, the response is slow and variable.
• Introduction of a stomach tube into the trachea prevents the mare from straining.
• Parenteral clenbuterol may help to stop the mare from straining.
• General anaesthesia may be considered for final manipulative attempts before a surgical approach.

**Manipulation**

• Whilst awaiting experienced help it is best to walk a mare with dystocia, to stop her from straining; this prevents further loss of fluid and reduces trauma to the reproductive tract.
• Vaginal examination should be made with a washed and lubricated ungloved hand – this aids the differentiation of the vaginal wall (if the cervix is closed), allantochorion and amnion.
• If the allantochorion is still intact it must be ruptured using a finger (nail), guarded knife or hypodermic needle – this membrane is very tough.
• If the amnion has not ruptured it is best to assess the situation and carry out preliminary manipulations through the membrane; this prevents loss of amniotic fluid and facilitates repositioning of appendages.
• Initially, attempts are made to ascertain the cause of dystocia and thereafter to correct abnormalities of posture and position – the latter involves the following techniques:
  _ Repelling any part of the fetus which is in the vagina to allow access to flexed appendages;
  _ Application of ropes to the head and fetlocks;
  _ Application of blunt eye hooks;
  _ The introduction of warm water or saline into the uterus where all the natural fluids have been lost;
  _ Applying traction to the foal, or attached ropes, once satisfactory posture and position have been achieved.
• Problems encountered during manipulation are:
  _ Observers often expect rapid results and do not understand the difficulties involved;
  _ The mare may be uncooperative;
  _ Pain (due to the mare straining) and tiredness of the operator’s arms make manipulation progressively more difficult;
  _ Drying of the mare’s vagina makes her resentful of repeated re-insertion of the arm – it is helpful to lubricate the arm regularly but not the operative hand (which is less effective when slippery);
  _ The ruptured amnion, particularly when trying to apply ropes to the head, constantly insinuates itself between hand and foal, and prevents the rope from gripping;
  _ Preventing a head (which appears reluctant to be born) from flopping back into the uterus can be difficult; this probably reflects failure of the body of the foal to rotate and it may be helpful if the mare is allowed to roll.
• Whilst applying traction to a foal, always consider:
  _ Is the vagina adequately lubricated?
  _ The direction of pull – once the fetal head is clear of the vulva the foal should be pulled towards the mare’s hocks;
  _ The strategy of traction – try to ensure that limbs are pulled alternately and in unison with the mare’s straining efforts – retain tension on the head;
Could the fetus be oversized? This is rare; have the hips locked? Once the head and forelimbs are delivered the rest of the birth should be easy. If this is not so it may be because of hip lock or hind-limb flexion (dog-sitting position); the latter cannot be diagnosed. In this case repel the foal if possible and rotate it into a lateral position—a large rotation of the front of the foal probably only affects the hips to a minor degree, and then apply traction again.

- When the foal is born by traction, the mare is often standing. Once the thorax starts to pass through the vulva call for assistance to support the foal to prevent trauma from falling and premature rupture of the cord.
- If the mare is recumbent after delivery, pull the foal’s forelegs round to the mare’s head to establish contact.
- Allow the cord to rupture spontaneously, do not ligate it; if haemorrhage occurs apply a haemostat temporarily.
- After any delivery, particularly if it is easy, check for a second fetus.
- The time at which manipulation and/or traction will have been considered to fail will depend on many factors, not least the possibility of quick surgical intervention.

**Embryotomy**

- Embryotomy involves the removal of part of the foal, *per vaginam*, either using a roughened wire or a knife.
- Embryotomy is best performed by an experienced obstetrician with appropriate guards to prevent trauma to the reproductive tract.
- Embryotomy should only be considered in the mare if it is felt that one incision will be sufficient to allow rapid delivery of the fetus or if there is no alternative.
- The most likely situations when embryotomy will be applicable to the mare are:
  - Hydrocephalus – removal of the head may be facilitated by first puncturing the cranium and releasing fluid.
  - Irreducible head/neck flexion.
  - Where there is no alternative.
- Consideration should always be given to the likelihood of vaginal/uterine trauma sustained by the mare.

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**Recent incidence of fetopelvic disproportion**

- **Breed of cattle**
- **Compare size of fetus and birth canal**
  - Clear evidence of fetopelvic disproportion
    - Calf alive – Cesarean section
    - Calf dead – Fetotomy
  - Possible evidence of fetopelvic disproportion
    - Calf alive – Trial traction
    - Calf distressed – Cesarean section
  - No evidence of fetopelvic disproportion
    - Calf alive – Trial traction
    - Calf dead – Trial traction
THE CAESAREAN OPERATION

The cow

The caesarean operation is a routine obstetric procedure in cattle practice which has high maternal and fetal survival rates and is less exhausting, speedier and safer than fetotomy. A prompt decision to perform a caesarean operation is important for optimum success. The need for urgent intervention is indicated if there is evidence of fetal hypoxia as shown by hyperactive movements of the fetus and expulsion of the meconium, identifiable in the amniotic fluid. A successful prognosis depends on several factors:

- skill and speed of the surgeon
- duration of dystocia
- availability of skilled assistance
- surgical environment
- concurrent disease
- presence of a live calf.

Indications

The reasons for surgery include most causes of dystocia but analysis of published cases shows that the following six major indications account cumulatively for 90% of all caesarean operations:

1. fetomaternal disproportion
2. incomplete dilatation of the cervix
3. irreducible uterine torsion
4. fetal monsters
5. faulty fetal disposition (presentation, position or posture)
6. fetal emphysema.

Incomplete cervical dilatation;

Incomplete dilatation of the cervix is a common cause of dystocia in cattle, but it should be diagnosed only after careful assessment of the findings on vaginal exploration. Cervical dilatation during the first stage of labour is a gradual process and the presence of a cervical rim is not in itself an indication of dystocia, provided that the fetal membranes are still intact. Care should be taken in such cases not to perforate the membranes unless the cervix remains undilated 2 hours or so later. Slow, or arrested, dilatation in multiparous cows may be associated with uterine inertia caused by hypocalcaemia; in these animals, the response to calcium therapy is rapid. If, on initial or subsequent examination, the cervix is incompletely dilated and the membranes are already ruptured, with a fetal extremity presented against or through the cervix, or if the fetus is already dead, then further cervical dilatation is unlikely. If the cervical rim is shallow and membranous, or if it stretches sufficiently for the head to be drawn into the vagina, normal safe delivery may be possible. In these cases, irrespective of the degree of dilatation, the cervix is usually too thickened and indurated for vaginal delivery to be safely attempted, and further delay results only in fetal death and a greater risk of intrauterine infection. The presence of an incompletely dilated cervix after the birth of one twin with the other fetus still in utero, often in a breech presentation, clearly indicates that the cervix constricts soon after becoming fully dilated. The frequent finding of faulty fetal disposition in cases of apparent failure to dilate may indicate that, in these cases at least, the cervix in fact is constricting and the dystocia is fetal rather than maternal in nature. Failure of the cervix to dilate or remain dilated is not uncommon in premature calvings and can
result in the fetal head becoming trapped in the anterior vagina. Incomplete dilatation of the cervix is an important complication of uterine torsion. After manipulative correction of the torsion, the cervix is often only partially dilated and seldom dilates further. In such cases, the cervical rim may be deep, but it is usually thin and stretches in response to traction on the fetus. Operation of the cervical rim in the midline dorsally during traction may allow safe vaginal delivery, but it should be remembered that the fetus (in cases of uterine torsion) is usually larger than normal and that a cervical incision may tear causing severe haemorrhage or uterine rupture.

Miscellaneous indications;

Occasionally, animals are encountered with full cervical dilatation and a normal-sized fetus, in which the caudal part of the birth canal is too constricted for delivery even after episiotomy. The condition is associated particularly with Friesian heifers which are sometimes older than is usual at the time of first calving. The natural termination of pathologically prolonged pregnancy may also be associated with absence of normal parturient changes in the vagina and vulva, and a consequent need for a caesarean operation. Abortion in late pregnancy sometimes requires treatment by a caesarean operation for several contributory reasons, such as incomplete birth canal dilatation, cervical constriction, fetal deformity and faulty fetal disposition. Such cases are uncommon, but they are nevertheless important because they may be associated with specific zoonotic infections. Fetal mummification and hydrops uteri may now be treated initially by inducing parturition, but a caesarean operation may still be necessary if induction fails or the birth canal is insufficiently dilated for vaginal delivery.

A two-stage caesarean operation for cases of hydroallantois. A left flank incision is made as for a normal caesarean operation. Once the uterus has been identified, large-bore sterile tubing is used to drain the allantoic fluid through a stab incision in the uterine wall and the tube is retained by a purse-string suture. The allantoic fluid is drained slowly, monitoring the pulse continuously; if the pulse accelerates, drainage is suspended for 10–15 minutes. When as much fluid as possible has been drained from the uterus, the tube is withdrawn and the purse-string suture closed. A routine caesarean operation is then performed, rather than waiting 24 hours. Laparotomy is essential in cases of uterine rupture. If this disorder occurs as a preparturient complication, the fetus usually lies totally within the peritoneal cavity and may survive if the cord is not twisted, until the placenta separates at term. More frequently, rupture occurs as a complication of dystocia, particularly of uterine torsion or as a result of manipulation of a fetus which is oversized or has faulty disposition. Uterine rupture during parturition may result in considerable uterine haemorrhage and hypovolaemic shock. Repeated dislocation of the sacrococcygeal articulation during assisted delivery in successive parturitions, or a healed pelvic fracture, can result in massive bony obstruction at the site and constitutes an uncommon indication for surgery.

Procedure

A caesarean operation may be performed with the dam standing, or in sternal, lateral or dorsal recumbency. The choice depends on the surgeon’s preference, demeanour of the animal and available facilities. For standing surgery, the animal should be restrained using a halter, preferably in a calving pen, tied such that the animal’s right flank is against a wall and the head is in the corner, in order to limit movement during surgery. The halter should be tied with a quick-release knot in case of recumbency. Nose bulldogs are often required for additional restraint. Sedation should be avoided if possible because it can cause recumbency during surgery and may be detrimental to
fetal survival. If sedation is necessary, xylazine is commonly used (0.05–0.1 mg/kg intramuscular or a reduced dose intravenously. xylazine is an ecobic, making surgery more difficult, and can cause ruminal bloat, which can obstruct the surgical wound. A rope can be attached to the right hind leg above the fetlock and laid underneath the animal’s body so that if the cow becomes recumbent during surgery, the rope can be pulled to enable the animal to lie in right lateral recumbency. The tail is tied out of reach of the operative site, usually to the halter or to the right hock. Two or more assistants are usually required for successful surgery: as a minimum, one to restrain the cow and one to deliver the calf. Communication with the assistants by the surgeon is important. Briefly describe how the surgery will be performed, and outline the role of each assistant and how to proceed in the case of a crisis such as recumbency of the cow during surgery. The location for surgery should be selected carefully with the objectives of ensuring good hygiene, lighting, facilities for restraint and a suitable floor surface. Avoid performing surgery in buildings occupied by large numbers of other cattle. Ideally, use a clean calving pen or other unoccupied building. Clean bedding should be provided, although vigorous shaking of straw will cause unwanted clouds of dust. Lighting should be provided that illuminates the desired surgical site. The surgeon should ensure that the light is not placed such that the surgical site is in the shadow cast by the surgeon; equally, the light must not shine in the eyes and distract the surgeon. Many veterinarians carry a portable halogen lamp and stand, for use on the farm; alternatively, one solution is for the surgeon to wear a head-torch.

**Anaesthesia.** The choice of anaesthetic method varies between surgeons and the selected surgical site. For flank incisions, paravertebral anaesthesia of the nerves associated with the transverse processes of T13, L1, L2 and L3 is indicated. Each site is infused using 20 ml of 2–3% lignocaine with adrenaline; 12–14 ml to block the ventral nerve branches, 6–8 ml for the dorsal branches. Signs of successful anaesthesia are a warm, hyperaemic and flaccid flank with no response to pain when tested with an 18 gauge 1.5 inch needle. The advantage of paravertebral anaesthesia is that the whole flank musculature is desensitised and flaccid, which facilitates exploration of the abdomen during surgery and closure of the wound. Also the flank incision can be extended readily if necessary during surgery. One disadvantage is that the technique is more difficult to perform than other methods. In addition, the cow may be unsteady after surgery due to loss of lumbar muscle tone and paresis of the ipsilateral hind limb. Finally, the vasodilatation in the muscle layers causes a greater degree of haemorrhage that requires careful haemostasis. A local anaesthetic line block or inverted-L block of the flank is an alternative to paravertebral anaesthesia. An 18 gauge 1.5 inch needle is used to administer 2% lignocaine with adrenaline at several sites; the number of sites is dependent on the length of the proposed incision. At each point, 5 ml of local anaesthetic is injected subcutaneously in each direction of the incision line, and a further 10 ml into the musculature. The technique is quick and reliable, and requires minimal training. However, the parietal peritoneum may not be effectively anaesthetised, causing reaction by the patient when it is incised. Sloss and Dufty (1977) reported particular problems of inadequate analgesia with an inverted-L block in fat animals. A similar reaction will occur if the incision has to be extended during surgery to extract the calf. Furthermore, because the flank is not flaccid, apposition and suturing of the muscle layers can be difficult, and there may be an adverse effect on wound healing. Epidural anaesthesia using lignocaine can provide adequate anaesthesia of the flank, although such anaesthesia also tends to cause recumbency, which may be prolonged in cattle. A wide surgical field should be
prepared. Initially, dirt and dust should be brushed from the flank and back of the animal before the operative field is clipped or shaved. In the case of a flank incision, the entire flank should be clipped from the transverse processes dorsally to the milk vein ventrally, and from the caudal ribs to the hind leg, level with the tuber coxae. The skin should be prepared using a surgical scrub (7.5% povidoneiodine or 4% chlorhexidine gluconate solution) followed by surgical spirit. Sterile drapes should be applied; in the standing animal a large single drape with a suitable window can be placed over the back of the cow and down the flank.

Operative technique

A vertical skin incision is made in the middle of the left flank starting 10 cm ventral to the transverse processes and extending approximately 30–40 cm long. Alternatively, a slightly oblique incision from caudo-dorsal to cranio-ventral, about 30° from vertical can be used, starting 10 cm from the tuber coxae. The advantage of oblique incision is that the internal abdominal oblique muscle can be split along its fibres and there is improved access to the genital tract. Potential disadvantages are incision of the circumflex iliac artery if the incision is extended too far caudo-dorsally and lack of anaesthesia if too far cranio-ventrally, when using a paravertebral anaesthetic. If the breed of dam or other indication for surgery suggests that future elective caesarean operations may be necessary, the first incision should be made at the cranial border of the flank, thus allowing for subsequent incisions more caudally. A ventrolateral incision is particularly indicated for the removal of an emphysematous fetus; the cow should be in right lateral recumbency. An oblique incision, starting from the flank fold dorsal to the attachment of the udder, is continued cranially, parallel to the ventral border of the ribs. The advantage of this approach is that it gives good exposure of the uterus, even when it is friable, and it minimises the risk of uterine contents contaminating the abdominal cavity. However, repair of the abdominal muscle layers can be more difficult if the muscles are under tension and sutures may tear through the tissue. A surgical drain may be inserted during repair of the wound, particularly if a dead fetus was delivered. A midline or paramedian incision is not commonly used in the field because general anaesthesia or heavy sedation is required and respiratory function of the dam is compromised. However, the technique gives excellent access to the uterus. A non-absorbable suture should be used for repair of all muscle layers of the incision because postoperative wound dehiscence has severe implications, including herniation. A right flank incision is uncommon; however, it is indicated if the left flank approach is obstructed by adhesions as a result of previous surgery. Access to the uterus is good, but the small intestines are difficult to retain within the abdomen and they interfere with the surgery. With left flank approach the following muscle layers are incised: cutaneous, external abdominal oblique, internal abdominal oblique and the transverse abdominal muscle. They are incised using a scalpel, unless the fibres can be split parallel to the skin incision. Haemorrhage from the muscle layers is usually minimal; however, when large vessels are involved, haemostats should be applied and the vessel ligatured if necessary. The peritoneum is incised using a scalpel, taking care not to puncture the rumen which lies immediately beneath the peritoneum. The uterus should be exteriorised by grasping and applying traction to
a distal extremity of the calf, usually the hindleg. To aid exteriorisation of a hindlimb the calf’s foot can be held using the surgeon’s right hand and the hock with the left hand, so levering the foot up through the incision. Manipulation of the uterus also causes stretching of the mesometrium and can cause pain manifested by grunting and the cow displaying other signs of discomfort. If the calf is in the right uterine horn, it will be necessary for the surgeon to rotate the uterus along its longitudinal axis to bring the calf’s limbs to the flank wound. Rotation can be achieved by traction on the leg with the left hand, whilst pushing the dorsal aspect of the uterus away from the surgeon with the flat of the right hand. A similar technique can be attempted, if the indication for caesarean operation was irreducible uterine torsion, to correct the torsion before incision of the uterus. The uterine wall is incised over the calf’s leg from toe to hock along the greater curvature and parallel to the longitudinal muscle layers of the myometrium. The incision can be made using a scalpel or scissors. The emphysematous fetus presents unavoidable risks of peritoneal contamination, not least because its hair and hooves may already have been shed. In such cases, incision of the uterus is often followed immediately by the escape of gas and fetid fluid; parts of the fetus may be grossly swollen and crepitate on handling. The uterine wall is often tightly stretched, and intrauterine manipulation can be difficult. Flank and uterine incisions of adequate length are therefore essential. A live calf should be immediately attended to by an assistant, whilst the surgeon examines the uterus, initially for the presence of a second fetus. In addition, any lacerations of the uterine wall should be noted and repaired. The fetal membranes are removed if they can be readily detached, which is uncommon. Otherwise, they are returned to the uterine lumen and any protruding tissue trimmed so that it is not incorporated in the suture line of the uterine incision. This approach is justified on two grounds. Firstly, it should be assumed that if the fetal membranes can physically be separated, they will be expelled naturally and more completely by uterine contractions. Secondly, if deliberate detachment of the fetal membranes is attempted before they would normally separate and be expelled, then there may be haemorrhage or incomplete removal either of microvilli or of larger masses of placental tissue. It is common practice to place antimicrobial pessaries in the uterine lumen before repair of the hysterotomy wound, but the value of these is questionable. If the fetal membranes are subsequently expelled naturally, so too are the pessaries. If they are retained, then the antimicrobials can have no more than a minimal local action in the lumen and are probably ineffective in controlling deep infection. The uterine wall is closed with a Lembert or Cushing suture, avoiding the allantochorion; if the latter membrane is included, the uterus may prolapse during third-stage parturition. Alternatively, a Lembert suture pattern can be used with the needle passing at right angles to the incision, or a Cushing pattern, where the needle passes parallel to the incision. Many surgeons oversew the first suture with a second continuous pattern, particularly if the uterus is friable where the suture material can tear through the tissues. Great care should be taken to avoid the fetal membranes being incorporated in the uterine repair. The peritoneal cavity should be closed as quickly as possible to reduce the chance of bacterial contamination. The abdominal flank incision should be repaired in three layers: peritoneum and transverse abdominal muscle, internal oblique muscle and external oblique muscle. A continuous suture pattern is used, starting at the ventral commisure of the incision for the first layer. Care is taken to appose the peritoneum and transverse abdominal muscle to avoid leakage of air from the abdominal cavity into the muscle layers following surgery. Antibiotics may be infused between each muscle layer; approximately 250 mg/ml each of procaine penicillin G and dihydrostreptomycin as a mixture is commonly
used. The skin is repaired using 5–7 Metric sheathed multifilament nylon in a Ford interlocking pattern. A single simple suture may be included at the dorsal and ventral aspects of the wound to allow drainage and/or flushing in the case of wound infection. Alternative suture patterns include a horizontal mattress or cruciate suture. The wound should be cleaned following surgery and the teats and udder examined. Oxytocin (20–40 i.u.) should be administered intramuscularly to stimulate further uterine involution. In addition, calcium borogluconate should be administered intravenously to mature dairy cows to prevent hypocalcaemia and facilitate uterine involution. A non-steroidal anti-inflammatory agent should be considered, at least in cases of animals that have had severe dystocia, uterine torsion or uterine infection prior to surgery. If there is evidence of surgical shock, intravenous fluid therapy is indicated; 2–3 litres of hypertonic (7.2%) sodium chloride are particularly effective. Antibiotic should be administered for an appropriate period, usually 3–5 days, or until the fetal membranes are expelled. The dam is often re-examined 24–48 hours after surgery and particular note of the rectal temperature, demeanour, appetite and faecal consistency should be noted. The faeces are often dry and the cow mildly constipated following surgery. Pyrexia, depression, inappetence and diarrhea may indicate peritonitis. If the fetal membranes have been retained, appropriate treatment should be instituted. Skin sutures are removed 3 weeks after surgery. In addition, a postnatal examination of the genital tract can be performed at this time because endometritis is more common following caesarean operation. Insemination should be delayed until >60 days postpartum.

**complications**

1-Subcutaneous emphysema:
Air often leaks from the abdominal cavity into the subcutaneous tissues and muscle layers following surgery if the peritoneum is not closely apposed, causing emphysema. The condition is more common in animals that have tenesmus after surgery, usually as a consequence of dystocia, and can extend as far as the shoulders in some cases. Dependent on the volume of air, the tissues return to normal in 1–8 weeks.

2-Metritis and retained fetal membranes:
Dystocia, twins, uterine torsion and fetal monsters are common indications for a caesarean operation; the procedure itself predisposes to retained fetal membranes. Removal of the membranes during surgery is rarely possible. However, if they are retained more than 24 hours after surgery, gentle attempts at removal can be made daily by exploration of the vagina only. Intravenous and intramuscular antibiotic can be administered, and once the membranes have been expelled, gentle lavage of the uterine lumen with 5 litres of warm, normal saline can be administered using a sterile widebore tube.

3-Peritoniti:
Diarrhoea, pyrexia, inappetence and abdominal pain are the common presenting signs of peritonitis following a caesarean operation. Fortunately, the omentum and/or the use of antimicrobial therapy often limit the peritonitis. However, in many instances there are recurrent cycles of peritonitis and healing leading to formation of extensive adhesions and chronic weight loss. Inadequate repair of the uterine incision, particularly in the presence of a metritis, is the principal cause of postoperative peritonitis. However, in some cases, the peritonitis may already exist at the time of surgery. The incidence is increased in the case of a dead or emphysematous fetus, after severe dystocia, rupture of the uterus or presence of a fetal monster, and after spillage of uterine fluids into the abdomen during surgery. A variety of treatments
have been suggested including parenteral antibiosis, intra-abdominal administration of antibiotic through the right flank, surgical lavage of the peritoneal cavity and intravenous fluid therapy.

4- Wound dehiscence:
As many as 6% of animals may have complications related to dehiscence, abscess or seroma formation around the abdominal incision. Predisposing factors for wound dehiscence include inadequate asepsis, low abdominal incisions, trauma to tissues during surgery, environmental contamination, tenesmus and a poor temperament of the animal after surgery. In addition, removal of skin sutures too early after surgery can lead to the incision line opening up; 3 weeks is a minimum period.

5- Nerve paralysis:
Animals that are recumbent during surgery have the risk of temporary or permanent peroneal nerve injury. In addition, a number of cows may have sustained trauma to the obturator nerve during dystocia prior to caesarean operation.

6- Fractures:
The dam may sustain a fracture whilst attempting to rise after surgery. However, more common is a long-bone fracture or growth plate separation of the calf during attempts to correct dystocia prior to caesarean operation.

7- Postpartum haemorrhage:
Haemorrhage from the abdominal incision is usually limited, although dependent on the haemostatic concern of the surgeon. However, haemorrhage from the uterine incision can be considerable and in some cases fatal, if the cotyledary vessels are disrupted. Occasionally the haemorrhage may be minimal at surgery, but may progress in the 24 hours following operation.

**The ewe**

**Indications**
The main indications for the caesarean operation in the ewe are:
- failure of the cervix to dilate
- irreducible or severely traumatised vaginal prolapse
- fetopelvic disproportion, particularly in primiparous animals with a single fetus
- fetal emphysema after protracted dystocia.

The left sublumbar region is close-clipped and the skin prepared for aseptic surgery. The skin is incised in the mid-sublumbar fossa, and the underlying muscles are incised in the same way as described above for the cow. However, it is important to stress that the body wall is very much thinner, and great care must be taken not to incise into the rumen accidently. It is also important in a high sublumbar incision to recognise the highly vascular mesometrial attachment to parietal peritoneum. A fetal extremity, preferably the hock, is grasped through the uterine wall so that an incision can be made in the same way as that described for the cow. The fetal membranes should be removed if they can be readily detached; if not, then that which cannot be returned to the uterine lumen, thus interfering with the closure of the uterine incision, should be excised. The uterus should be closed using a single inversion suture pattern such as Lembert’s or Cushing’s, using an adsorbable material. The sheep, more than any other species, is highly susceptible to the toxaemic effects of intrauterine clostridial infection, and most deaths are due to this complication.

**Torsion of the uterus**
Torsion of the uterus, or part of it, is seen as a cause of dystocia in all domestic species. However, there is a wide variation in its frequency between species which is
generally considered to be due to differences in suspension of the tubular genital tract which affects the 'stability' of the gravid tract.

Rotation of the uterus on its long axis, with twisting of the anterior vagina, is a common cause of bovine dystocia.

**Etiology:**

Uterine torsion is a complication of late first-stage or early second-stage labour. It is probably due to instability of the bovine uterus, which results from the greater curvature of the organ being dorsal, and the uterus being disposed cranially to its subbilial suspension by the broad ligaments. However, there must be some contributory factor additional to instability that operates during first-stage labour; otherwise, torsion would be more frequently seen during advanced pregnancy than at parturition.

The precipitating parturient factor is probably the violent fetal movements, which occur in response to the increasing frequency and amplitude of uterine contractions during the first stage of parturition, as it assumes the normal disposition for normal birth. Excessive fetal weight is also a predisposing factor. The final factor that allows the uterus to rotate about its longitudinal axis occurs when the cow is attempting to rise to her feet from sternal recumbency, particularly when she is in a confined space. She first flexes her forelimbs so that she bears her weight on both knees (carpal joints); this is followed by a forward lurching movement of the head and whole body so that both hind legs can be extended; she is now resting on her knees and hind feet. At this stage, she may well rest temporarily, before making the final effort to extend the flexed carpal joints and stand on all four feet. When the cow is bearing her weight on knees and fully extended hind limbs, the longitudinal axis of the uterus will be almost vertical, thus allowing it to rotate quite easily about this axis if violent fetal movements occur at this stage. The presence of bicornally disposed bovine twins would appear to stabilise the parturient uterus, and this view is supported by the great rarity of torsion in twin pregnancy. However, in ewes the anatomical attachment of the mesometrium is sublumbar rather than subbilial as in cattle and bicornual gestation is very common, yet uterine torsion occurs.

**Clinical features:**

The consensus of veterinary opinion is that torsion in an anticlockwise direction (as viewed from behind the cow) is more common than in the other direction, and accounts for about 75% of cases. Although the uterus rotates about its longitudinal axis the actual twist in the majority of cases involves the anterior vagina; in the minority of cases in which the twist affects the posterior part of the uterus there is minimal distortion of the vaginal walls. It is generally believed to occur during the first stage of labour, because immediately after it has been corrected the cervix is found to be dilated to a variable degree. However, if after correction, the cervix is found to be fully dilated, or if before correction, the membranes are ruptured and portions of them or the fetus are protruding through the cervix, the inference should be that the torsion occurred during early second-stage labour. Torsions of less than 180° cause little interference with gestation, and that they often arise during advanced pregnancy and may persist for weeks or months, being recognized only when they cause dystocia at term. Torsions of 45–90° are often detected at pregnancy diagnosis and that they probably undergo spontaneous correction.

**Symptoms:**

Up to the onset of parturition the animal has been normal, and when it enters the first stage of labour the usual signs of restlessness due to subacute abdominal pain associated with myometrial contractions and cervical dilatation are shown. In the typical case, the only real symptom is that the period of restlessness is abnormally
protracted or that it wanes and does not progress into second-stage labour. If the torsion does not occur until early second-stage labour, then a short period of straining will have followed the restlessness, but will have ceased abruptly. In severe cases of torsion there may be increasing restlessness, but more probably all parturient behaviour will cease and, unless the animal has been closely observed, there may be no knowledge that parturition has begun. Slight depression of the lumbosacral spine as a frequent symptom. If the condition is unrelieved, the placenta will separate and the fetus will die. There will develop persistent low-grade abdominal pain, progressive anorexia and constipation. Because the fetal membranes often remain intact, secondary bacterial infection of the fetus will develop later than with other forms of dystocia. In one study, there was pyrexia (23%), tachycardia (93%), tachypnoea (84%), straining (23%), anorexia (18%) and a vaginal discharge (13%).

**Diagnosis:**
Diagnosis is readily made by palpating the stenosed anterior vagina, whose walls are usually disposed in oblique spirals which indicate the direction of the uterine rotation. The cervix may not be immediately palpable, but by carefully following the folds into the narrowing vagina, the lubricated fingers can usually be pressed gently forwards and through the partially dilated cervix. Where the site of the twist is precervical, the vagina is much less involved, and diagnosis is assisted by palpating the uterus per rectum. In torsions of less than 180° portions of the fetus may enter the vagina and the dystocia may be wrongly ascribed to faulty fetal position (lateral or ventral).
**Prognosis**  This is quite good in cases that are recognized and dealt with promptly. In cases that have not been treated for some time after they occurred severe compromise of the blood supply to the uterus may occur. In such cases the calf may die and the uterine wall may become necrotic and friable. Uterine rupture may occur spontaneously or at attempted treatment by rolling, and peritonitis, toxemia, and death may occur. The possibility of unseen uterine damage should always be remembered in cases in which treatment has been delayed or which do not do well after treatment.

**Treatment**  A number of methods are available:

*Rotation of the fetus and uterus per vaginam back into their correct position*  This is possible if the obstetrician’s hand can pass into the uterus and touch the fetus and if fetal fluids remain within the uterus. The fetus is grasped by a convenient prominence such as the elbow, sternum, or thigh and is rocked from side to side before being pushed right over in the opposite direction to the torsion (Fig. 4.3). If the maneuver has been successful the torsion will have disappeared and the vagina regains its normal morphology.

*Rolling the cow*  The principle of this method is to roll the cow around its uterus while that organ remains
still. Three assistants are required. The cow is cast on the side to which the torsion is directed (Fig. 4.4). Thus in an anticlockwise torsion she is cast on her left side. The two forelegs and the two hindlegs are tied together and the head is restrained with a halter or head collar. The cow is rolled sharply over onto her other (right) side. The patency of the vagina is checked and if the torsion persists the cow is gently rolled back onto her other (left) side and the process is repeated. The cow may have to be rolled two or three times before the torsion is corrected.

The efficiency of rolling can be improved by putting external pressure on the cow’s abdomen in an attempt to ‘hold the uterus still’ while the cow’s body is rolled. Manual pressure over the uterus can be used or a board rested against the caudal abdomen and downward pressure exerted by a person standing on it.

The calf should always be delivered by the obstetrician as soon as the torsion has been corrected. The cervix may close within 30 minutes of resolution of the torsion preventing fetal delivery by the vaginal route and necessitating cesarean section.
Surgical correction This may be necessary if fetal rotation is impossible and rolling the cow is unsuccessful. A left flank laparotomy is performed on the standing cow under local anesthetic (see also Chapter 11). The uterus is located and the direction of the torsion confirmed by palpating and examining the cervical region. The uterine wall or a fetal limb within the uterus is grasped firmly and an attempt made to rotate the uterus back into its correct position.

Once the uterus is correctly in place the calf may be delivered per vaginam or by cesarean section. If the uterus cannot be rotated cesarean section must be performed with the uterus in its abnormal position. Once the fetus has been delivered the uterus can normally be readily rotated into its correct position after repair of the uterine wall. The condition of the uterine wall should be carefully checked before abdominal closure. If the uterus is discolored, its blood supply may have been compromised. If normal color is not restored after correction of the torsion the prospects for survival are not good. Antibiotic cover and the administration of a non-steroidal anti-inflammatory drug such as flunixin may aid recovery and provide analgesia.

1. Torsion of the uterus during pregnancy

Clinical signs Uterine torsion should always be considered when signs of colic occur in mares during late gestation. Mild colic can occur in any pregnant mare and may be associated with fetal movements and
pressure on pelvic nerves and blood vessels. Such colic are non-progressive and usually resolve rapidly without treatment. Occasionally, analgesia may be required. Any more serious or persistent colic should be fully investigated. In summary, a full history is taken and the mare subjected to a complete clinical examination in case a serious gastrointestinal problem has developed incidentally in the pregnant mare. A rectal examination is performed to examine the accessible parts of the abdomen for signs of abnormality involving the gastrointestinal tract. A stomach tube is passed to check for evidence of gastric reflux and the abdomen is auscultated to assess bowel activity. An abdominal paracentesis is performed to obtain a sample of peritoneal fluid. The latter technique is often unproductive in late pregnancy because paracentesis at this time usually results in the collection of allantoic rather than peritoneal fluid.

Specific findings with uterine torsion during pregnancy include:
- mild to quite severe unremitting colic
- slight elevation of the pulse; packed cell volume is usually normal
- normal bowel activity and sounds
- scant but normal peritoneal fluid
- rectal examination: reveals displacement of the uterus and its broad ligaments. The pregnant uterus lies laterally and is displaced from its normal midline position
- vaginal examination: usually no abnormality. Most cases during pregnancy are pre-cervical and have little effect upon the vagina.

During rectal examination the uterus may be felt to deviate sharply laterally and downwards instead of being readily palpable in the midline. The fetus may not be palpable and the uterus is immobile. The broad ligaments are displaced and may be tense, especially on the side of the animal towards which the uterus is rotated. Thus if the uterus is rotated to the right the right broad ligament may be palpated per rectum as a tense band running from the right sublumbar region down to and under the uterus. The left broad ligament runs from the dorsal aspect of the displaced uterus to the left sublumbar area. Right and left uterine displacement occur with equal frequency.

**Treatment**

The state of the uterine wall must be taken into account: it may be firm or compromised if the torsion has been present for some time. Fetal compromise may have also occurred if the placenta has been damaged. Fetal death may occur in cases of prolonged torsion. Economic considerations are also important, as is the quality of the surgical facilities available. Three methods of treatment may be considered:

1. **Replacement of the uterus by manual manipulation:** an attempt is made to grasp the uterine wall per rectum, rock the uterus from side to side, and then swing it back into the correct position. Great care must be taken to avoid damaging the rectal and vaginal walls and this method is only likely to be successful if the uterine torsion is recent and the fetus small. If successful, the uterus resumes its midline position and the signs of colic rapidly resolve.

2. **Rolling the mare under general anesthesia:** this can be attempted if the previous method fails, but should not be used in late gestation. The mare is placed on the side to which the torsion is directed and then sharply rolled over in the direction of the twist. It may be necessary to repeat the procedure and external pressure on the uterus and fetus may be supplied using a board — on which an assistant stands — as in the cow. The procedure is not without risk but may be considered if laparotomy is not possible for economic or other reasons.

3. **Replacement of the uterus via laparotomy:** this can be attempted in the standing or recumbent mare.

Standing flank laparotomy in the sedated mare and under local infiltration anesthesia is performed on the side towards which the torsion is directed. A small incision is made in the center of the sublumbar fossa initially to allow the obstetrician's hand to grasp the uterus. The uterus is rocked backwards and forwards away from and towards the operator and then turned back into its correct position. Occasionally, bilateral incisions may be required.

Ventral midline laparotomy is performed under general anesthesia and allows better access to the abdomen and uterus. Good surgical facilities are mandatory. The direction of the torsion is checked and an attempt made to rock or replace the uterus into its correct position. If satisfactorily replaced, the uterus and its broad ligaments should be in their correct position and under normal tension.

The abdomen may be more readily checked for gastrointestinal abnormalities during a ventral midline laparotomy. If the uterine wall is compromised it may be possible to repair damage and if there is clear evidence of fetal death then cesarean section can be employed to remove it. Severe damage or disruption of the blood supply to the uterine wall carries a grave prognosis.
Preoperative antibiotic and non-steroidal anti-inflammatory therapy are recommended.

**Management of the mare and fetus after correction of uterine torsion** The prognosis following treatment — especially rolling or surgery — must be guarded. There is a risk of placental separation with fetal death, uterine rupture, peritonitis, or other postprocedure complications. In one survey, 70% of foals known to be alive at surgery were born alive at term.

Following correction of uterine torsion, the foal should be monitored carefully after treatment. A transabdominal ultrasonographic scan should be performed daily to monitor the fetal heart beat and the clarity of the amniotic fluid. The scan should be carried out daily for the first week and weekly after that until term. Fetal survival will depend on whether there has been any compromise of placental function. It has been suggested that a compromised placenta produces insufficient progesterone to maintain pregnancy. 2.2 mg/50 kg body weight daily of the synthetic progestagen algnestan can be given orally to the mare in such cases in an attempt to support maintenance of pregnancy. The drug is withdrawn slowly and with reducing dose towards the end of pregnancy. The efficacy of the drug therapy has not been scientifically proven.

2. **Torsion of the uterus as a cause of dystocia at term**

**Clinical signs** Suspicions of uterine torsion may arise if there are signs of colic and delay in the early stages of birth. In parturient mares the point of torsion is normally anterior to the cervix. Vaginal examination may reveal some constriction of the birth canal and displacement of the broad ligaments may be confirmed on rectal examination. The fetus may be displaced anteriorly and not as easily palpated as in other forms of dystocia. In some cases the uterine torsion is associated with an abnormal disposition of the foal, which may be found in a lateral or ventral position.

**Treatment** If good surgical facilities are available an immediate cesarean section is advisable to deal with this abnormality. If immediate surgery is not contemplated and access can be gained to the fetus an attempt should be made to correct the torsion by rotating the fetus and surrounding uterus back into its normal position. The obstetrician's hand is fully inserted into the birth canal and the fetus is grasped by the neck or shoulder. The fetus and uterus are rocked from side to side and then sharply turned in the opposite direction to the torsion. Several attempts may be necessary to correct the problem. Once the torsion has been dealt with the fetus should be delivered manually. Great care must be taken as the viability of the uterus and possibly vaginal walls may have been compromised or more severely damaged by interference with the blood supply during the period of torsion. Gentle massage of accessible tissues may encourage relaxation and facilitate delivery.

If rotation of the uterus per vaginam is not successful a ventral midline approach to the uterus should be made at surgery. At laparotomy the uterus is inspected and rotated into its correct position. It may be advisable to deliver the foal by cesarean section to avoid further complications. Standard postoperative care and management are required.

Rolling the mare at term is accompanied by grave risks of uterine rupture and should not be attempted.

**Downward deviation of the uterus**

This may be a problem in mares that have suffered a ventral hernia. If the pregnant uterus passes into the sac of the hernia the fetus may hang almost vertically down from the pelvis. Exit from the uterus may be occluded and fetal delivery is compromised. The start of parturition should be closely monitored and manual assistance given with delivery of the foal. The severity of the hernia may be reduced and fetal delivery assisted by support for the ventral abdominal wall. A canvas sling passing around the abdomen and supported by the mare's spine may be found useful as in cases of rupture of the prepubic tendon (see p. 83). Fetal delivery is more easily completed in the recumbent mare. The abdominal floor may be raised in the quiet standing mare by using a sack under the abdomen held and lifted by two assistants one on either side of the patient. In a nervous mare, sedation or casting may be necessary to cause her to lie down. Traction is applied to the foal to bring it up into and through the maternal pelvis.

**FETOPELVIC DISPROPORTION**

This is seldom a problem in mares although it has been reported in Belgian Draft mares where double-muscled, which greatly increases fetal size, occurs. It is occasionally seen in other breeds including ponies. Prolonged gestation in mares, in total contrast to the position in cattle, does not result in fetal oversize. In fact, quite the reverse. Foals are quite frequently carried for 4 weeks
CESAREAN SECTION IN THE COW

Indications

1. Resolution of existing dystocia
   - Fetopelvic disproportion including cases of misalliance and postmaturity.
   - Fetal maldisposition, which cannot be corrected by manipulation.
   - Irreducible uterine torsion.
   - Incomplete dilation of cervix or other parts of birth canal.
   - Fetal monsters that cannot be delivered by other means.
   - Uterine rupture or severe uterine hemorrhage.
   - Damaged and severe vaginal prolapse where further damage might accompany vaginal delivery.

2. Elective cesarean section
   - Surgical termination of prolonged gestation.
   - To avoid existing or suspected fetopelvic disproportion.
   - Termination of pregnancy in cases of life-threatening disease in the dam: for example, some cases of hydrops allantois and traumatic reticulitis or pericarditis. Induction of birth might be used as an alternative in such cases but the time required for the drugs to work may not be compatible with maternal life.
Flank laparotomy

**Advantages**  Only local anesthesia is required, the incision may be easily extended if necessary, the risk of postoperative soiling of the wound or herniation is small.

**Disadvantages**  The uterus is often difficult to exteriorize prior to opening, the peritoneum is readily contaminated with uterine contents especially if the calf is dead and emphysematous.

In left-flank laparotomy the rumen may occasionally make access to the uterus difficult but the risk of the small intestine falling out of the wound is normally small.

Right-flank laparotomy allows good access to a calf in the right uterine horn but the risk of loops of small intestine tending to slip out of the laparotomy incision is higher.

Flank laparotomy can be performed on the standing or laterally recumbent cow. Surgery on the standing patient is preferred by most obstetricians if the patient is likely to remain standing and not go down suddenly during surgery. Opening and closure of the peritoneal cavity is often a more straightforward procedure in the standing patient. There is less intra-abdominal pressure but exteriorization of the uterus can be difficult in some cases. If the cow is thought likely to go down during surgery it is probably better to sedate, cast, and restrain her in sternal or lateral recumbency with the upper hindleg pulled back.

Ventrolateral or midline laparotomy

**Advantages**  The uterus (even one containing an emphysematous calf) can more readily be exteriorized with less risk of peritoneal contamination.

**Disadvantages**  Heavy sedation or general anesthesia is required, the risk of postoperative soiling of the incision or herniation is higher.
Figure 11.9 Bovine cesarean section – ventralateral approach.
'Fetotomy' (often termed 'embryotomy') is the term used to describe methods of dividing a fetus, which cannot be delivered, into small pieces that will more readily pass through the birth canal. The technique should be used only when the fetus is known to be dead. Fetotomy is used most commonly in cattle, occasionally in horses, rarely in sheep and goats, and almost never in pigs and small animals. Fetotomy can be complete, when a whole fetus is divided into smaller pieces, or partial, when a small part of the fetus, such as a leg, is removed.

Two techniques of fetotomy are available – percutaneous and subcutaneous:

- In *percutaneous fetotomy* a tubular embryotome is used, through which a flexible wire saw is passed. The wire saw is used to cut through the fetus while the embryotome protects the maternal tissues from damage.
- In *subcutaneous fetotomy* parts of the fetus are dissected out from within its skin, thus reducing fetal bulk and allowing delivery of the remainder through the birth canal.

Percutaneous fetotomy is the preferred method unless the fetus is in a very decomposed state and can readily be broken up by hand.

**indications**

- The relief of dystocia caused by fetal maldisposition that cannot be corrected by manipulative means.
- The relief of dystocia caused by fetopelvic disproportion in which the fetus is dead and cannot be removed by traction. The fetus may be normal but oversized or it may be abnormal as a fetal monster.
- The relief of dystocia caused by the fetus becoming stuck during delivery – for example in the cow when...
stifle lock (sometimes termed ‘hip lock’) occurs after the head and part of the fetal thorax have been delivered.

- During cesarean section when the dead fetus is either too large to remove from the uterus in the normal way, is deformed, or is in a maldisposition that cannot be corrected.

Figure 12.1 Fetotomy equipment. (A) Tubular embriotome, (B) fetotomy wire, (C) handles for wire, (D) handle for embriotome, (E) screw to tighten handle, (F) introducer, (G) threader, (H) cleaning brush.
THE TECHNIQUE OF PERCUTANEOUS FETOTOMY

The use of the embryotome

The fetotomy wire must be threaded through one or both tubes of the instrument before use:

- If the fetal part to be sectioned is directly accessible (e.g. the head of a calf in normal anterior presentation) both tubes are threaded, the handles are attached and the loop of wire at the end of the tubes is placed around the part in question.
- If the fetal part to be sectioned is not directly accessible and the wire cannot be looped around it (e.g. a foreclimb in shoulder flexion), only one tube of the embryotome is threaded. The other end of the wire is attached to the introducer, which is passed around the part to be sectioned and pulled out of the birth canal before being passed through the second tube of the embryotome.

Placement of the wire in all cases is facilitated by generous use of obstetric lubricant. Two liters or more should be instilled into the uterus and topped up as required. Once in position, the wire is pulled tight and the obstetrician carefully checks its position. Sawing is commenced by the assistant using long strokes. The embryotome is held firmly in position by the obstetrician. Initially the wire may take a little time to engage in the skin of the part being sectioned and short sawing strokes are used at this stage. Muscle is readily sawn through but more effort is required for bony tissue. The efficiency of sawing is increased if the part to be sectioned is under a little tension and if the embryotome can be held still as the wire is engaging. If the fetal head is being removed by sectioning the neck this tension can be supplied by applying moderate traction to the head using a calving rope applied in the normal way or using self-tightening hooks engaged in the flesh of the fetus.

Occasionally the wire breaks as it is being used, especially if it has been used before. In such cases the embryotome must be re-threaded and the process started again. The risk of breakage is reduced by using a length of wire in good condition and avoiding the development of kinks in the wire by keeping it under slight tension at all times once it is threaded through the embryotome.
Progress may be checked manually by the obstetrician at intervals, who must ensure that the assistant does not move the wire saw while checking is taking place. If possible, the obstetrician should ensure that the fetotomy wire does not come in contact with the uterine wall. This may be done by trying to hold the uterine wall away from the head of the embryotome.

Once the fetal part has been cut through the movements of the wire will suddenly encounter much less resistance. The embryotome is then removed and the sectioned fetal part is retrieved and removed. In most cases bone will have been sectioned and great care must be taken during removal to ensure that the birth canal is not damaged by sharp bony fragments.

**Complete fetotomy**

**Fetus in anterior presentation**

**Removal of the head**
- If protruding from the vulva: attach a rope to the head and simply cut the head off with a stout knife or scalpel by disarticulating the neck as low down and close to the shoulders as possible.
- If within the vagina: loop the fetotomy wire over the head and back along to the base of the neck. Saw through as close to the shoulders as possible (Fig. 12.2).

**Removal of a foreleg** A loop of fetotomy wire is passed along the leg to be removed. The loop is guided over the top of the scapula. The threaded embryotome is brought up on the medial aspect of the leg (Fig. 12.3). Sawing is commenced, with frequent checks that the position of the wire and progress are satisfactory. The wire is sometimes difficult to keep in position over the top of the scapula – making a small incision in the skin between the scapula and the withers with scalpel or knife may help.

An alternative technique using acute-angle sawing with the embryotome can be used to remove a foreleg. The threaded embryotome is passed forwards along the lateral aspect of the limb to be removed to just beyond the dorsal edge of the scapula. The loop of the wire is on the medial aspect of the limb. The wire is tightened and sawing is commenced holding the embryotome firmly in position just dorsal to the scapula. The wire saws through the tissues between the limb and the chest wall. With this method there is less risk that the embryotome wire will fail to cut between the scapula and the fetal chest wall. There is a slightly increased risk that the embryotome wire may break.

**Further fetotomy** Having removed one forelimb and the head it may then be necessary to remove the other forelimb. The procedure already described is repeated on the second leg.

**Removal of the thorax** The next stage is to remove the thorax of the calf by sawing the body across caudal to the ribs in the lumbar region. A generous loop of wire threaded through the embryotome is worked carefully over the thorax using plenty of lubrication and easing it forward a little bit at a time. The embryotome is introduced into the vagina and the wire tightened. The point of section must be caudal to the last rib.
(Fig. 12.4). Once the body has been sectioned the thorax can be gently removed. The fetal abdominal viscera will have been exposed and are removed manually.

If the fetus is large it may be necessary to remove the fetal thorax in two parts. The first transverse incision is made just caudal to the attachment of the forelimbs and the second caudal to the last rib. If the fetal rib cage separated by the two transverse incisions is too wide to pass through the pelvic canal it may be partially collapsed by making a longitudinal incision with the embryotome at the junction of the ribs and the thoracic vertebrae on one side.

Division of the pelvis The rear end of the calf remains in the uterus after removal of the thorax. The severed lumbar vertebrae are sharp and care must be exercised to prevent them damaging the uterus. Although it may occasionally be possible to remove the remainder of the calf without further section,
It is mostly necessary to divide the pelvic girdle longitudinally so that the caudal part of the calf may be removed in two smaller parts.

A length of wire is threaded through one tube of the embriotome and is attached to an introducer. The introducer is carried into the uterus and is dropped over the dorsal aspect of the rear end of the fetus as near to the fetal midline as possible. The obstetrician seizes the introducer beneath the ventral aspect of the rear end of the calf. The hand is introduced between the hindlegs of the fetus as they extend anteriorly in the uterus. Once the introducer with wire attached is located it is pulled out with its attached wire placed between the hindlegs of the calf. The introducer is removed from the end of the wire, which is then pulled through the embriotome using the threader. The wire is tightened and the embriotome is placed against the anterior surface of the fetal pelvis (Fig. 12.5). Sawing is commenced, having made certain 'by checking at intervals' that the wire is going to cut between the ischial tuberosities of the pelvis. This will ensure that the pelvis is divided into two roughly equal parts. Sectioning the pelvis may be helped by holding it in position by applying traction to it through a pair of self-tightening hooks. When the hind end is divided, one half at a time is removed, taking care to protect the dam from damage from the exposed sawn-through and pelvic edges.

**Fetus in posterior presentation**

**Hindlimb removal** A loop of fetotomy wire is passed up the limb so that the end of the loop lies anterior and medial to the wing of the fetal ilium. A small incision in the skin with a scalpel will help the wire saw to become embedded here. The head of the embriotome is placed between the fetal ischial tuberosities and the loop arranged so that the cut includes the tail—a procedure that will stop the tendency for the wire to slip down the leg.

An alternative method using acute-angle sawing with the embriotome may be used to remove the hindlimb. The threaded embriotome is passed along the lateral aspect of the limb to be removed to just beyond the tuber coxae on that side. The wire loop passes up the medial aspect of the limb. Sawing is commenced and the embriotome is held firmly just anterior to the tuber coxae (Fig. 12.6). The wire sections the fetal pelvis and the limb attached to part of the pelvis is carefully removed. With this method it may be easier to ensure that the embriotomy incision is on the medial aspect of the tuber coxae. There is a slightly increased risk that the embriotomy wire may break.

Should it be necessary the other hindlimb can be similarly removed. The body of the calf can then be divided in the lumbar region or further forward by passing a loop of wire forward as already described for anterior presentation. Forelegs can be removed with the aid of the introducer to put the wire over the shoulder joint, i.e. between the neck and the forelimb. Alternatively, the anterior part of the body can be divided longitudinally.

**Partial fetotomy**

This technique may be required to facilitate delivery of a dead fetus in which manual correction of malposition has proved impossible.

**Deviation of the head** The fetotomy wire is passed around the base of the neck using an introducer. The base of the neck is sectioned as low down as possible and the head and part of the neck are removed (Fig. 12.7).
Shoulder flexion  The fetotomy wire is passed between the fetal thorax and the medial aspect of the retained limb using an introducer. The skin between thorax and limb is incised to assist placement of the fetotomy wire. The aim is to cut through the muscular attachment between forelimb and body wall.

Breech presentation (bilateral hip flexion)  The fetotomy wire is passed between the medial aspect of retained thigh and the fetal abdominal wall using an introducer. The second tube of the embryotome is threaded and the wire tightened. If possible, a skin incision is made in the fetus to ensure that the
Figure 12.8 Fetotomy – removal of a hindlimb from a calf with irreducible bilateral hip flexion (breech presentation).

Figure 12.9 Fetotomy – removal of a portion of a hindlimb with irreducible hock flexion.

cut is made on the medial aspect of the fetal tuber coxae (Fig. 12.8). The limb is removed after section. The space now available may allow retrieval of the second limb and its conversion into a posterior presentation with delivery by traction. If this is not possible, the second limb is removed by fetotomy in the same way as the first. The remainder of the fetus is then delivered by traction. Self-closing hooks may be attached to the fetus so that traction may be employed.