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RECENT ADVANCES IN REPRODUCTIVE PHYSIOLOGY: IMPLICATIONS FOR CONTROL OF FERTILITY AND FECUNDITY OF SHEEP AND CATTLE

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Improvements in the control of reproduction in sheep and cattle are sought for many reasons. This paper looks at work done to regulate reproduction in the female rather than in the male.

RESEARCH TECHNIQUES

In considering recent physiological developments in knowledge of reproduction in the ewe and cow, some mention should be made of the rapid advances in techniques of study. Probably the most notable advance has been the increased ability to quantitate the hormones secreted from endocrine organs and the levels of these hormones circulating in the blood. At first these studies were confined to the measurement of a few hormones in blood draining endocrine glands while others could be measured only by assaying gland contents. Now, as a result of a new series of techniques, most hormones believed to be of importance in reproduction can be measured in peripheral blood and secretion rates from endocrine glands calculated.

Methods currently being used in endocrine laboratories include gas liquid chromatography (GLC), mass spectrometry and combinations of GLC and mass spectrometry, double isotope dilution derivative assay, radio-immunoassay and competitive protein binding assays. Some of these assays are suitable only for measurement of hormones in concentrated endocrine gland effluent while others are of much higher sensitivity and may measure hormones in the peripheral blood. A major advance was made as recently as 1972 when it became possible to measure ovine follicle stimulating hormone (FSH) in peripheral blood (L'Hermite *et al.*, 1972; Salamonsen *et al.*, 1973).

Virtually all reproductive hormones are active at concentrations of less than 10 mg/ml blood. However, no technique is currently available to accurately measure oestradiol-17β (E_2)

in peripheral blood throughout the oestrous cycle in ewes where values are in the low picogram range. It is possible to detect the high levels reached prior to parturition (Challis, 1971).

The inability to measure secretion rates in conscious animals over extended periods of time led to the surgical preparation of animals that enabled convenient access to the affluent and effluent blood supplies of endocrine glands. Probably the most notable, in the field of reproduction, has been where the ovary was transplanted to a previously-fashioned jugular carotid loop (Goding *et al.*, 1967). Such animals rarely showed behavioural oestrus and commonly had prolonged corpus luteum function (Baird *et al.*, 1968; McCracken and Baird, 1969). Autotransplantation of the uterus in addition to the ovary to this site in the neck allows normal cycles to occur and behavioural oestrus is evident. The role of the uterus as an endocrine organ secreting prostaglandin (PG) $F_{2\alpha}$ and the need for an anatomical relationship between the uterus and the ovary have been elucidated by these preparations.

Paralleling these spectacular advances considerable understanding of various mechanisms involved in the reproductive process has come from the application of a variety of techniques ranging from embryo transplantation to simple laparotomy. Thus for example the latter technique has allowed the determination in the field of reasons for differences in reproductive rate of ewes between farms (Chopping and Lindsay, 1970). The variety of techniques available is also exemplified in pregnancy diagnosis in the ewe where methods have included X-ray examination to recto-abdominal probing of the uterus.

ATTAINMENT OF REPRODUCTIVE RESEARCH OBJECTIVES

The objectives of physiological research into reproduction in sheep and cattle can be grouped under three broad headings:

(1) Increased fertility and fecundity;

(2) Control of reproduction to facilitate genetic improvement; and

(3) Control of reproduction for improved farm management.

Simple aids to approach these objectives are available. Some of these, like the use of ram and bull mating harnesses, have had wide application as in the overmating of ewes with subsequent reduction in number of dry ewes and late lambers in the flock, or in the detection of high rates of returns to service of particular beef bulls. Other aids such as the side branding of cows using hair bleaches to facilitate easy individual identification of oestrous cows in the paddock may help in improving conception rates following artificial breeding in both dairy and beef cattle. Likewise rectal palpation and subsequent culling of dry cows should not be overlooked as a simple yet effective technique in improving herd management.

Even such a simple procedure as weighing ewes prior to and at mating and applying the knowledge gained has enabled farms to increase flock reproductive performance by manipulation of the ewe's liveweight. The observation by Coop (1962) that there was a strong relationship between increased liveweight and increased lambing percentage appears to have been widely recognized by farmers in New Zealand (*e.g.*, delay in the time of mating to allow liveweight increase in ewes to occur following the end of a summer drought feeding period) and has also led to several studies that have shown that the liveweight effect is mediated through ovulation rate. This is illustrated in Fig. 1 (Cumming, 1972) which shows data for ovulation rates recorded at laparotomies in December, February, April and June in 250 Saxon Merino ewes that were managed on pasture in an attempt to maintain constant liveweight. For each mating the ewes were ranked according to liveweight

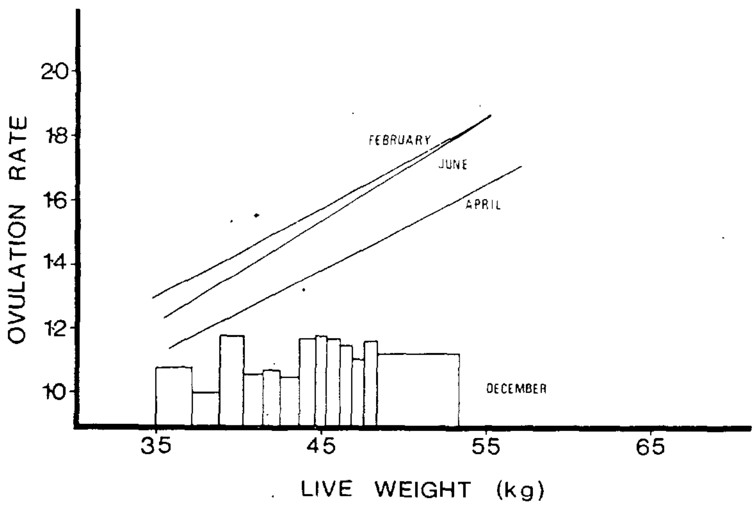

FIG. 1: *Association of liveweight at mating and ovulation rate in Merino ewes, December, February, April and June.*

and the data from descending groups of 20 ewes were averaged and regression analysis applied (Ovulation Rate $= a + bLW + cLW^2 + dLW^3$, where LW = liveweight). There was a low ovulation response in December (1.12 corpora lutea per ewe) but this increased in February (1.48), April (1.36) and June (1.44), and it was at these latter three periods that there was the marked increase in ovulation rate with increase in liveweight. The small reduction in mean ovulation rate in April may have been associated with a fall in the plane of nutrition during the period. It is opportune to stress that in relation to the management of sheep on pasture, there is little precise information available (among quite a lot reported on the practice of flushing of sheep) on how pasture quality and ovulation rate or lambing percentage may be interrelated. There are considerable problems with such investigations yet such information is required by the farmer seeking to "prepare his pastures" and increase sheep production per unit area.

Some techniques to improve reproductive performance are not quite so simple as those already mentioned and demand a good understanding of the reproductive process and a high level of management for optimal results. A few examples may illustrate these procedures. Gonadotrophin stimulation of ewes on Days 12 and 13 of the oestrous cycle can be used to increase lambing performance (Wallace, 1954). This treatment must be accurately timed and the dose response for each breed must be known. A further extension of controlled breeding has been the development of the intravaginal progestagen pessary. This method of hormone administration can be used successfully to synchronize oestrus at the second oestrus following pessary withdrawal without impairment to fertility (Robinson, 1967).

Extensive studies have been conducted on the hormone control of breeding (mostly in sheep), yet the application of the results in the form of practical methods regularly applied by farmers does not seem great. Despite this, the control of reproduction in sheep, especially where high lamb production is sought, can be promoted (Gordon, 1972).

The search for and interest in sheep breeds (and individuals) of high prolificacy has drawn attention to the reasons for reproductive differences (ovulation rate, uterine capacity, mothering ability and lamb survival). The crossbred offspring of these highly prolific breeds and those of lower fecundity generally produce progeny with reproductive performances intermediate between the parent breeds (Donald *et al.*, 1968). Results from crossbreeding for increased productivity along with that of selection within breeds (for high fecundity), indicate that the physiological characters for prolificacy are inherited. Systems of sheep production that exploit the superior reproductive characteristics of certain breeds and crosses are employed in New Zealand but could be further extended (Coop, 1972). In addition, commercial farmers and stud breeders also seek techniques to enable the early recognition of prolificacy and the superior animals utilized for breeding purposes. To do this many farmers are saving flock replacements from ewe hoggets of high liveweight, or with early puberty, or from those which lambed or conceived early in the season. The recent finding that differences existed in luteinizing hormone (LH) in peripheral blood of 30-day-old Merino lambs from three flocks which showed fertility differences, and also that within a flock sire differences existed (Bindon, 1973), could be of much practical use. Hormone and other indicators of potential prolificacy that might be measured directly in the male as well as the female are sought.

In summary, most of the above procedures were developed before the availability of the present sophisticated laboratory techniques and their application to reproductive research. It is expected that from the use of these new techniques there will flow useful practical developments for controlling reproduction. These will be based on a detailed knowledge of the physiology of the oestrous cycle, pregnancy and parturition.

OESTROUS CYCLE

This can be conveniently discussed by reference to the changes seen in the ovary during the cycle: (1) The luteal phase and luteolysis; (2) The follicular phase and ovulation.

Luteal Phase and Luteolysis

Following ovulation a corpus luteum (CL) is formed. This gland secretes progesterone throughout the luteal phase (ewe $\simeq$ 15 days; cow $\simeq$ 18 days) of the oestrous cycle. However, large and rapid fluctuations in progesterone levels in peripheral blood do occur during the luteal phase (Obst, 1972). The CL will function only if the pituitary is secreting LH and prolactin.

Also, within the ovaries there appears to be a series of independent follicles which grow and then regress. Oestradiol-17β is secreted from the sheep follicle as it matures and prior to the follicle commencing atresia. In the sheep a number of these follicular waves have been shown to occur starting on Days 2 to 4 of the oestrous cycle and following at 4- to 6-day intervals (Cox *et al.*, 1971; Holst *et al.*, 1972).

It would appear likely that the E_2 secreted by these follicles acts on the uterus which in response secretes $PGF_2\alpha$ (Caldwell *et al.*, 1972). This $PGF_2\alpha$ then influences luteal function by causing depression in progesterone production (Nancarrow *et al.*, 1973), and presumably for cyclic activity the production of $PGF_2\alpha$ must be of sufficient magnitude and duration to cause the complete regression of the corpus luteum. This process of regression is termed luteolysis and it is only after it has occurred that an animal may next return to oestrus and to ovulate.

In the presence of progesterone the E_2 secreted by the follicles cannot cause the pre-ovulatory release of LH which is necessary for ovulation to occur (Cumming *et al.*, 1971). If the objective is to synchronize oestrous cycles two approaches may be adopted: (1) The suppression of ovulation and oestrous activity by maintaining for a desired period high levels of progesterone or related compounds; or by (2) Causing luteolysis to occur at a chosen time. There has been considerable work done on the first approach and progestagens have been given by injection, orally, by intravaginal pessary or subcutaneous implant and all of these methods are currently in use although their limitations are recognized.

The second approach is considered now in more detail in the light of current knowledge. Removal of the uterus results in the CL being maintained for a length approximating normal pregnancy. A number of surgical procedures (some previously described) have confirmed that the presence of a uterine hormone adjacent to the ovary containing the corpus luteum is necessary for luteal regression. A series of experiments have shown that $PGF_2\alpha$ is secreted from the uterus into the uterine vein. The utero-ovarian vein is closely adherent to the ovarian artery and $PGF_2\alpha$ moves between these two vessels down a concentration gradient (Goding *et al.*, 1972b) thus reaching the ovary without passage through the lung, an organ which achieves almost total clearance of $PGF_2\alpha$ (Piper *et al.*, 1970; Piper and Vane, 1971).

In the sheep and cow $PGF_2\alpha$ has been administered directly into the ipsilateral uterine horn and has synchronized oestrus (Goding *et al.*, 1972b). In the cow this was infused through an inseminating pipette but this was not possible in the sheep owing to the anatomical structure of the cervix. The minimum effective dose to cause luteal regression was in the cow 400 µg/hour for 6 hours (7 µg/kg) and in the sheep 50 µg/hour for 9 hours (8 µg/kg). Obviously a more practical method of administration is required and Rowson *et al.* (1972) showed that two injections of $PGF_2\alpha$ into the ipsilateral horn 25 hours apart were effective. This method likewise has limitation. It is impossible in sheep and cattle because there is the risk of uterine infection. A single treatment without the necessity to inject into the uterus would seem preferable.

A massive single injection of $PGF_{2}\alpha$ to an intramuscular site may yet be economically feasible with reduced cost of material. However, a more likely alternative to this treatment will be the use of prostaglandin analogues which are not cleared as rapidly as $PGF_{2}\alpha$ by the lungs. Such compounds could be given as a single intramuscular injection. Assuming such a compound becomes available commercially the ineffectiveness of PGs to cause luteolysis when given to animals very early in the cycle (sheep: Hearnshaw *et al.*, 1973; cow: I. A. Cumming, M.E.D. Cerini and D. H. Pemberton, pers. comm.) or when given very late in the cycle after CL regression has occurred, will mean that a proportion of animals will not be synchronized during a single period. Such animals should be selected prior to first treatment (drafted out) and held for an injection given when all animals would be in the mid-luteal phase.

With synchronization of ovulation, the detection of oestrus becomes unnecessary if AB is to be used provided the time of ovulation can be predicted. Investigation of this aspect is required. PGs show promise of having applications in the controlled mating of farm animals particularly in the use of AB but also in beef herds and in those dairy herds where oestrus detection is difficult.

Follicular Development and Ovulation

The waves of follicular growth that occur during the oestrous cycle continue but following luteolysis the E_2 released by maturing follicles can cause the pre-ovulatory LH release and ovulation follows rather than atresia as occurs during the luteal phase.

The reason for a limited number of follicles developing in any one follicular wave is unknown. For a long time it had been assumed that an increased output of FSH resulted in increased follicular growth prior to ovulation. Prior to the recent development of assays for FSH in peripheral blood, it was assumed that a surge of FSH was released which in turn stimulated growth and maturation of the follicle. However, recent studies (L'Hermite *et al*, 1972; Salamonsen *et al.*, 1973) have failed to show any such release. Instead it might be suggested that the basal levels of FSH control follicular growth and an understanding of these is still required.

Exogenous gonadotrophins, PMSG or FSH, will stimulate follicular growth and subsequently the number of ovulations, yet the variation in response remains a limitation to the application of this approach to increasing the levels of fecundity. It is known that the time of PMSG treatment in respect to luteolysis is critical. With the ability to control luteolysis by using $PGF_{2}\alpha$ or its analogues, exogenous gonadotrophins could be given at a time exactly related to the physiological events occurring within the ovary.

Thus, with the development of suitable management procedures for controlling luteolysis, useful procedures to control fecundity will likely follow. Immediate benefits of such procedures are obvious in the beef industry where a greater incidence of twinning cows and multiple suckling would be profitable.

Overriding control of pituitary function is centred at the hypothalamic level. For example, experimental evidence suggests that the E_2 released by the ovarian follicle acts directly at the hypothalamus to release a gonadotrophin releasing hormone (Gn-RH). This Gn-RH is a decapeptide, now characterized (Schally *et al.*, 1971; Burgus *et al.*, 1972) and synthesized. The Gn-RH acts upon the pituitary and causes the preovulatory release of LH and FSH (Cumming *et al.*, 1972; Jones *et al.*, 1973). Physiological studies have as yet not identified the mechanisms controlling the basal secretion of LH and FSH (Goding *et al.*, 1973). However, it has been established that there is a release of Gn-RH immediately prior to the LH peak (Kerdelhue and Jutisz, 1972) and that Gn-RH can release LH and FSH both in the presence and absence of progesterone (Cumming *et al.*, 1972) and it therefore follows that the E_2 must release Gn-RH from the hypothalamus in sufficient quantities to cause an LH/FSH peak only in the absence of progesterone.

Recent research in the sheep has shown that a single Gn-RH administration can cause ovulation in a proportion of animals in seasonal anoestrus (Cumming *et al.*, 1972), lactational anoestrus (B. J. Restall, pers. comm.) and even during early pregnancy (W. A. Chamley, J. K. Findlay, I. A. Cumming, J. M. Buckmaster and J. R. Goding, pers. comm.) It would appear that the single Gn-RH treatment releases a single surge of LH and FSH. Ovulation will follow only if a mature follicle is present on the ovary. To successfully initiate ovulation in all animals repeated treatment may be necessary.

The management problems of seasonal and lactational anoestrus in sheep and cattle may be reduced by using releasing factors to cause ovulation. During seasonal anoestrus in the sheep the pituitary contains sufficient LH to give a preovulatory-like surge in response to Gn-RH. However, the problem of lactational anoestrus is more difficult. During pregnancy in the sheep there is a progressive decrease in pituitary LH content and/or a progressive increase in refractoriness to Gn-RH (Chamley *et al.*, 1973). Thus Gn-RH will only be effective in causing ovulation after a post-partum interval in which LH pituitary content is increased and/or the refractoriness is removed. None of the basic knowledge is yet documented for the cow.

The above discussion on releasing factors has been centred on control of the pre-ovulatory LH/FSH peaks. Current research is directed at identifying hypothalamic hormones which control basal gonadotrophin secretion. In this understanding possibly lies the future control of multiple follicular growth and multiple ovulation.

The desirability of predicting the time of ovulation has already been mentioned. There seems to be a number of physiological events closely timed with ovulation. For instance strict time relationships occur between onset of LH peak and ovulation (Cumming *et al.*, 1973). However, the time relationship is not so close for onset of oestrus to ovulation. It is desirable to inseminate about the time of ovulation to achieve maximum fertilization of ova and viability of offspring.

The time of ovulation may be predicted after the peak of endogenous LH has been determined, LH injected, or following Gn-RH-induced LH release, provided a receptive follicle is present. The use of these exogenous treatments (LH or Gn-RH) following luteolysis initiated by PG analogues, may ensure optimum timing for successful AB programmes.

PREGNANCY

In pregnancy the CL is maintained until immediately prior to parturition. For the first 55 days of the sheep's pregnancy the CL is necessary until the endocrine role of the placenta is capable of supplying the needs for embryo survival. At present the mechanism whereby the tiny embryo prevents CL regression has not been defined; those being explored include a gonadotrophin of embryonic origin which will maintain luteal function in the presence of $PGF_{2}\alpha$, a local inhibitory factor which suppresses $PGF_{2}\alpha$ secretion by the uterus, and a factor which inhibits the transport of $PGF_{2}\alpha$ to the ovary (Goding *et al.*, 1972a).

The occurrence of substantial losses of early embryos during pregnancy and the return of some ewes to oestrus raises the question whether these losses could be reduced by overcoming the luteolytic effects of endogenous $PGF_{2}\alpha$. Attempts to augment ovarian and pituitary endocrine production by gonadotrophin and steroid therapy have not been successful.

Much research has centred on the problem of early embryo loss, especially in the sheep, and several factors have been associated with increased embryonic deaths (see Edey, 1969). Despite attempts to reduce the effect of these identified factors significant embryonic losses still remain. One approach to overcoming the effect of such prenatal loss is to ensure that increased numbers of fertilized ova reach the uterus. Several experiments have established that the uterus is capable of supporting numbers of embryos above that normally acceptable in practice (Lawson and Rowson, 1972). Thus while embryo losses still remain the effect of an increased ovulation rate is to cause an increase in the number of offspring born. Thus increased fecundity can arise from either or both of increased ovulation rate and decreased embryo loss.

While most prenatal losses occur early in pregnancy, it should not be overlooked that marked losses can occur during later stages of gestation owing to factors such as disease and undernutrition.

Methods for satisfactorily increasing twinning in beef cows have yet to be developed. The variable response to injected gonadotrophin makes it unlikely that techniques for super ovulation can be applied with sufficient precision to regularly induce twin ovulations. Furthermore, few twin calves will develop when both ovulations occur in the same ovary and the embryos commence to grow in the adjacent uterine horn. Rowson *et al.* (1971) reported that where a single egg was placed in each horn then a twinning rate of 73% was achieved, but that fewer twin calves (45%) occurred where both eggs developed in the same horn. Encouraging results have occurred in trials where a second egg was inserted through the cervix and placed in the uterine horn contralateral to that containing the naturally-produced ovum (R. A. S. Lawson and L. E. A. Rawson, pers. comm.). The technique of non-surgical egg transfer in the cow has been a long sought goal and its field application will be assisted by the development of methods for *in vitro* storage of cattle eggs as reported by Tervit *et al.* (1972). The successful freezing ($-196°$ and $-269°$ C) of mouse embryos and their later development to full term (Whittingham, 1971; Whittingham *et al.*, 1972) must point the way to a technique of value in future cattle genetics and production.

Egg transplantation as a technique for use in animal propagation has suddenly gained prominence in several countries. It is clear that considerable information already exists to allow the successful application of egg transplantation to increasing a small number of chosen animals. In New Zealand there has occurred the importation of Friesian and Jersey heifers carrying foetuses of the Simmental and Limousin breeds, and, because of quarantine measures, this has saved by several years the time taken to establish these exotic breeds in this country. Egg transfer as an aid in multiplying some of these animals is likely to be adopted. Distance need pose no problem as the transport of cattle ova *in vitro* or when held in the uterus of the rabbit is possible. Details of how long cow eggs will survive in the rabbit oviduct without increased wastage on re-transfer to the recipient cow have been reported (Lawson, 1970).

PARTURITION

This phase of the reproduction process and some of the events which initiate it are now better understood since it was realized that the pituitary-adrenal gland axis of the foetus is involved in the termination of pregnancy (Liggins, 1969). There has been the practical discovery that a single injection of long-acting corticosteroids will enable the cow to calve 1 to 3 weeks after treatment (Welch, 1971). Provided the calves are born within the last 6 weeks of gestation many will survive although variable results have occurred and the technique is thus not entirely satisfactory (Welch, 1972). The uncertainty of conception dates of animals in many herds, and so reduction in the effectiveness of the treatment, illustrates the need for reliable information on mating procedures and sound herd management. The use of the technique in New Zealand over the past four years has resulted in many potential late-calving cows lactating earlier than expected and the lactations have appeared normal. Other uses for such a technique include advancement of calving to equate better with feed supply; early calving with an increased lactation interval to reduce problems of re-breeding multiple suckling cows; and early delivery of lightweight calves from heifers especially those mated to sires of the heavy breeds.

Deaths of lambs (through non-infectious causes) at or within a few days of birth still remain as a major source of lamb loss in many flocks. With the development of free-lambing, "easy-care" sheep there may be a lower incidence of perinatal loss, provided nutrition is satisfactory for desired foetal growth and the ewes are physically active. Satisfactory methods for the detection of ewes with single and multiple foetuses may yet be developed and would facilitate the differential feeding of these animals. The need for this is emphasized with intensive systems of sheep production where feed availability and animal requirements are similar, and in flocks where significant percentages of ewes produce twins.

A restricted period for lambing offers possible advantages if single and twin-bearing ewes are to be differentially fed.

CONCLUSION

There have been a number of recent developments in physiological research that will be of use in improving reproduction in sheep and cattle. There is now considerable knowledge of the mechanisms involved in the regulation of the various stages of the cycle and pregnancy and of the inherent variation that exists at particular times.

Dramatic responses to exogenous hormones can be produced and controlled breeding is possible, yet variation in responses often reduces the effectiveness of these treatments. The application of some hormonal techniques to improving reproduction in flocks and herds has usually not been as successful as desired when tested on a large scale or repeated under conditions of the farm rather than the small paddock on the research station. Nevertheless, with further development and modification it is expected that certain techniques for controlled breeding will be of practical benefit in specialized systems of management.

Under all conditions, and especially in large flocks and herds, improvements in reproductive performance will continue to come from the manipulation of the environment and better management of the animals. The reproductive process in the female is comprised of co-ordinated events and its successful conclusion is dependent upon the weakest link. Because considerable variation exists in ovulation rate, embryonic survival, lamb survival, etc., there is scope for improved management that will enable reproduction at a high level to be attained, limited only by the animal's genetic ceiling. This concept is well known yet it needs emphasis.

REFERENCES

Baird, D. T.; Goding, J. R.; Ichikawa, Y.; McCracken, J. A., 1968: *J. Endocr.*, *42*: 283.

Bindon, B. M., 1973: *J. Reprod. Fert.*, *32*: 347.

Burgus, R; Butcher, M.; Amos, M.; Ling, N.; Monahan, M.; Rivier, J.; Fellows, R.; Blackwell, R.; Vale, W.; Guillemin, R., 1972: *Proc. natn. Acad. Sci.*, Wash., *69*: 278.

Caldwell, B. V.; Tillson, S. A.; Brock, W. A.; Speroff, C., 1972: *Prostaglandins*, *1*.

Challis, J. R. G., 1971: *Nature, Lond.*, *229*: 208.

Chopping, M. H.; Lindsay, D. R., 1970: *Proc. Aust. Soc. Anim. Prod.*, *8*: 312.

Chamley, W. A.; Findlay, J. K.; Cumming, I. A.; Buckmaster, J. M.; Goding, J. R., 1973: *J. Reprod. Fert.* (in press).

Coop, I. E., 1962: *N.Z. Jl agric. Res.*, *5:* 249.
Coop, I. E., 1972: *Proc. N.Z. Soc. Anim. Prod.*, *32:* 178.
Cox, R. I.; Mattner, P. E.; Thorburn, G. D., 1971: *J. Endocr.*, *49:* 345.
Cumming, I. A., 1972: Studies of the physiology of the oestrous cycle and early pregnancy in the sheep. Ph.D. Thesis, University of Melbourne.
Cumming, I. A.; Brown, J. M.; Blockey, M. A. de B.; Goding, J. R., 1971: *J. Reprod. Fert.*, *24:* 148.
Cumming, I. A.; Brown, J. M.; Cerini, J.; Cerini, M. E.; Chamley, W. A.; Findlay, J. K.; Goding, J. R., 1972: *Neuroendocr.*, *10:* 338.
Cumming, I. A.; Buckmaster, J. M.; Blockey, M. A. de B.; Goding, J. R.; Winfield, C. G.; Baxter, R. W., 1973: *Biol. Reprod.* (in press).
Donald, H. P.; Read, J. L.; Russel, W. S., 1968: *Anim. Prod.*, *10:* 413.
Edey, T. N., 1969: *Anim. Breed. Abstr.*, *37:* 173.
Goding, J. R.; Buckmaster, J. M.; Cerini, J. C.; Cerini, M. E. D.; Chamley, W. A.; Cumming, I. A.; Fell, L. R.; Findlay, J. K.; Jonas, H., 1972a: *Proc. Int. Congr. Endocr.*, Washington.
Goding, J. R.; Cumming, I. A.; Chamley, W. A.; Brown, J. M.; Cain, M. D.; Cerini, J. C.; Cerini, M. E. D.; Findlay, J. K.; O'Shea, J. D.; Pemberton, D. H., 1972b: *Hormones and Antagonists Gynec. Invest.*, *2:* 73.
Goding, J. R.; Buckmaster, J. M.; Cerini, J. C.; Cerini, M. E. D.; Chamley, W. A.; Cumming, I. A.; Fell, L. R.; Findlay, J. K.; Jonas, H., 1973: *J. Reprod. Fert.*, *18:* 31 (supplement).
Goding, J. R.; McCracken, J. A.; Baird, D. T., 1967: *J. Endocr.*, *39:* 37.
Gordon, I., 1972: *Irish Dept. Agric. & Fish. J.*, *68:* 3.
Hearnshaw, H.; Restall, B. J.; Gleeson, A., 1973: *J. Reprod. Fert.*, *32:* 322.
Holst, P. J.; Braden, A. W. H.; Mattner, P. E., 1972: *J. Reprod. Fert.*, *28:* 136.
Jonas, H. A.; Salamonsen, L. A.; Burger, H. G.; Chamley, W. A.; Cumming, I. A.; Findlay, J. K.; Goding, J. R., 1973: *Endocrinology* (in press).
Kerdelhue, B.; Jutisz, M., 1972: *Excerpta Med. int. Cong. Series 256:* 141.
Lawson, R. A. S., 1970: Embryonic survival in the ewe and cow under experimental conditions. Ph.D. Thesis, University of Cambridge.
Lawson, R. A. S.; Rowson, L. E. A., 1972: *J. Reprod. Fert.*, *28:* 433.
Liggins, C. G., 1969: In *Foetal Autonomy*, Ed. G. E. W. Wolstenholme, M. O'Connor, Ciba Symp. Churchill, London.
L'Hermite, M.; Niswender, G. D.; Reichert Jr, L. E.; Midgley Jr, A. R., 1972: *Biol. Reprod.*, *6:* 325.
McCracken, J. A.; Baird, D. T., 1969: In *The Gonads* (Ed. K. W. McKerns), Appleton, New York, Chap. 7, p. 175.
Nancarrow, C. D.; Buckmaster, J.; Chamley, W.; Cox, R. I.; Cumming, I. A.; Cummins, C.; Drinan, J. P.; Findlay, J. K.; Goding, J. R.; Restall, B. J.; Schneider, W.; Thorburn, G. D., 1973: *J. Reprod. Fert.*, *32:* 320.
Obst, J. M., 1972: Hormone studies on ewes grazing Yarloop clover. Ph.D. Thesis, University of Adelaide.
Piper, P. J.; Vane, J. R.; Wylie, J. H., 1970: *Nature, Lond.*, *225:* 600.
Piper, P. J.; Vane, J. R., 1971: *Ann. N.Y. Acad. Sci.*, *180:* 363.
Robinson, T. J., 1967: In *Control of Ovulation in the Sheep*, Sydney Univ. Press, Sydney.

Rowson, L. E. A.; Lawson, R. A. S.; Moor, R. M., 1971: *J. Reprod. Fert., 25:* 261.
Rowson, L. E. A.; Tervit, H. R.; Brand, A., 1972: *J. Reprod. Fert., 29:* 145.
Salamonsen, L. A.; Jonas, H. A.; Burger, H. G.; Buckmaster, J. M.; Chamley, W. A.; Cumming, I. A.; Findlay, J. K.; Goding, J. R., 1973: *Endocrinology* (in press).
Schally, A. V.; Arimura, A.; Kastin, A. J., 1971: *Research in Reprod., 3* (6): 1.
Tervit, H. R.; Whittingham, D. G.; Rowson, L. E. A., 1972: *J. Reprod. Fert., 30:* 493.
Wallace, L R., 1954: *J. agric. Sci., Camb., 4:* 60.
Welch, R. A. S., 1971: *Proc. Ruakura Fmrs' Conf. Week,* 105.
Welch, R. A. S., 1972: *Proc. Ruakura Fmrs' Conf. Week,* 167.
Whittingham, D. G., 1971: *Nature, Lond, 233:* 125
Whittingham, D G.; Leibo, S. P.; Mazur, T., 1972: *Science N.Y., 178:* 411.