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Handbook of Estrous Synchronization

Western Region Publication No. 014
May 2005
www.oardc.ohio-state.edu/estroussynch

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Handbook of Estrous Synchronization

Authors

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Abstract

Over the past 15 years, many systems to synchronize estrus in beef cattle have been developed and/or optimized. This progress has been driven by scientific discoveries that have arisen from fundamental research into the reproductive physiology and endocrinology of this species. From these discoveries, many of the reproductive endpoints that must be met to effectively synchronize estrus have been identified or refined. This has led to development of a wide variety of systems of varying complexity that effectively synchronize estrus and/or ovulation when used on the appropriate classification of female cattle. An applied understanding of the estrous cycle in cattle, the challenges presented by anestrous cows and prepubertal heifers, the commercial products available for this purpose, and the impact of these products on the reproductive system of cattle is necessary to choose the appropriate system of estrus synchronization for a given situation. An awareness of the production and physiological requirements of estrous control and the limits placed upon this process by the seasonal nature of beef cattle production and the physiology of cattle is essential. Finally, the details of the treatments given within each system and a working knowledge of the purpose of each step within a program are necessary to choose a suitable system of estrous synchronization and correctly apply this system. The information presented is based primarily on research performed in *Bos taurus* beef cattle, and limitations exist for some of the described programs in beef cattle with a large percentage of *Bos indicus* breeding. These limitations are described further in the summary of this publication. Likewise, while many of the programs described are effective in lactating dairy cows, the intent is that the information presented be applied to female beef cattle of predominantly *Bos taurus* parentage.

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Foreword

Members of Multi-State Regional Project W-112 (Reproductive Performance in Domestic Ruminants) have worked as a group for more than 30 years to obtain a better understanding of the basic physiological mechanisms controlling the estrous cycle of beef cattle. Information obtained by this group and others has led to the development of several effective systems of estrous synchronization for beef cattle. This publication provides a source of applied information that will permit readers of varying educational backgrounds to understand the process of estrous synchronization in beef cattle of predominantly *Bos taurus* parentage and enable them to apply the existing technology in an appropriate manner.

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The Estrous Cycle

Cattle are in heat (estrus) approximately every 21 days, with the normal range being 17 to 24 days. This periodic pattern of sexual receptivity is the result of an organized and complex series of changes that occur in the reproductive system of cattle. This 21-day sequence of changes is collectively referred to as the *estrous cycle.* The systems of estrous control that are used to synchronize or induce heat are designed to manipulate various components or functions of the estrous cycle. In order to manipulate various components or functions of the estrous cycle to synchronize or induce heat, it is necessary to understand the estrous cycle.

The primary glands or tissues that control the estrous cycle are the hypothalamus, pituitary, ovary, and uterus. Each of these components of the reproductive system secretes chemical compounds called hormones, which regulate their own function, or the function of other components. Many hormones are involved in control of the estrous cycle, and their release into the bloodstream can be measured experimentally. The major hormones, which are most commonly manipulated or administered to animals to synchronize estrus, are outlined in Table 1.

Table 1: Site of Production and Commercially Available Hormones Used for Estrous Control.		
Gland	**Hormone (Abbreviation)**	**Commercial Products[1]**
Hypothalamus	Gonadotropin Releasing Hormone (GnRH)	Cystorelin®, Factrel®, Fertagyl®, OvaCyst®
Pituitary	Luteinizing Hormone (LH)	Not used in current systems.
	Follicle Stimulating Hormone (FSH)	Folltropin®
Ovary		
− Follicles	Estradiol	Not used in current systems.
− *Corpus luteum*	Progesterone	Melengestrol acetate (MGA®), Intravaginal Progesterone Releasing Insert (CIDR®)
Uterus	Prostaglandin $F^2\alpha$ (PGF)	Lutalyse®, Estrumate®, ProstaMate®, In Sync®

[1] The commercial products often do not have the same chemical composition as the hormone produced by the animal's body. These compounds do have similar effects on the reproductive system of cattle. Compounds that have actions similar to progesterone are called progestins.

The hormones listed in Table 1 influence the secretion of other hormones and the function of the components of the reproductive system to cause and control estrus, ovulation, formation and regression of the corpus luteum, and the growth of follicles in the ovaries. The overall aim of estrous control systems is to make some, or all, of these physiological changes occur in all animals at the same time, in order to synchronize the timing of artificial insemination (AI).

The 21-day interval between heats in cattle reflects the lifespan of a structure on the ovary called the *corpus luteum* (CL). Figure 1 illustrates the process of formation, development, and regression of the CL. The CL originates from a preovulatory follicle that is present on the day the animal is in heat (Day 0). A preovulatory follicle is a fluid-filled structure on the ovary, which contains the egg to be fertilized (ovum) and layers of cells around the wall of the structure. This follicle produces the hormone estradiol, which causes the animal to show estrus and is responsible for inducing hormonal changes that will cause this follicle to ovulate.

On Day 1, the preovulatory follicle ruptures or *ovulates* and releases the ovum into the oviduct. On Days 2 to 5, important changes occur in the cells that line the ovulated follicle. These cells are transformed, or *luteinized,* into the structure called the CL. A primary function of the CL is to produce progesterone — the *pro-gestational*

hormone. As the name implies, this hormone supports pregnancy. If the egg released on Day 1 is fertilized, the CL will be maintained throughout the pregnancy, and the progesterone secreted helps support this pregnancy.

In terms of estrous synchronization, a very important function of progesterone is that if it is present in the blood stream of female cattle, they will not show heat. We use this to our advantage in controlling the estrous cycles of cattle. If the animal is not pregnant, this structure will be maintained on the ovary until approximately Day 17. At this time, the cow's reproductive system has recognized that she is not pregnant. The uterus then secretes the hormone prostaglandin $F_2\alpha$ (PGF). This hormone causes the CL to regress. This results in a decline in progesterone production, the formation of a new preovulatory follicle, increased estradiol production, estrus, and another opportunity for the female to conceive.

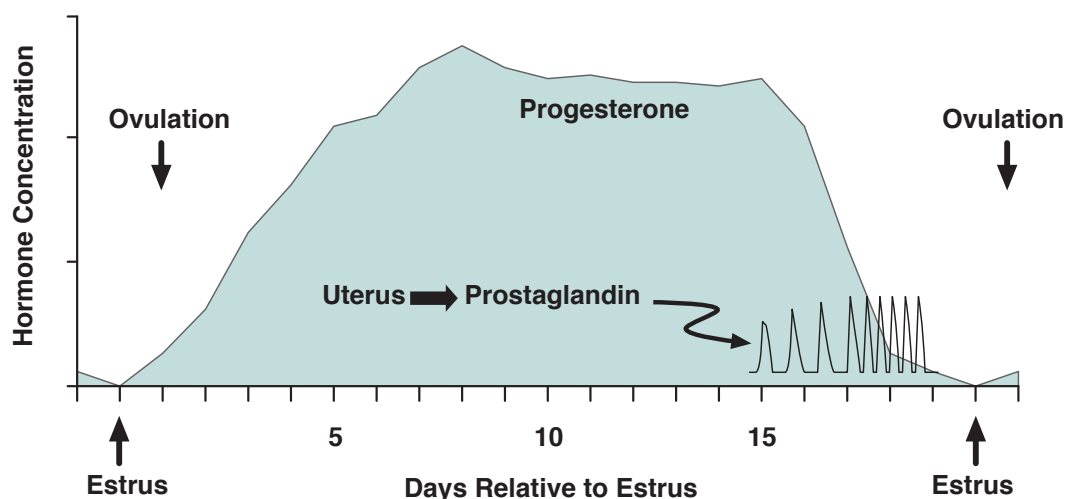## Figure 1. Formation of the Corpus Luteum in Cattle.
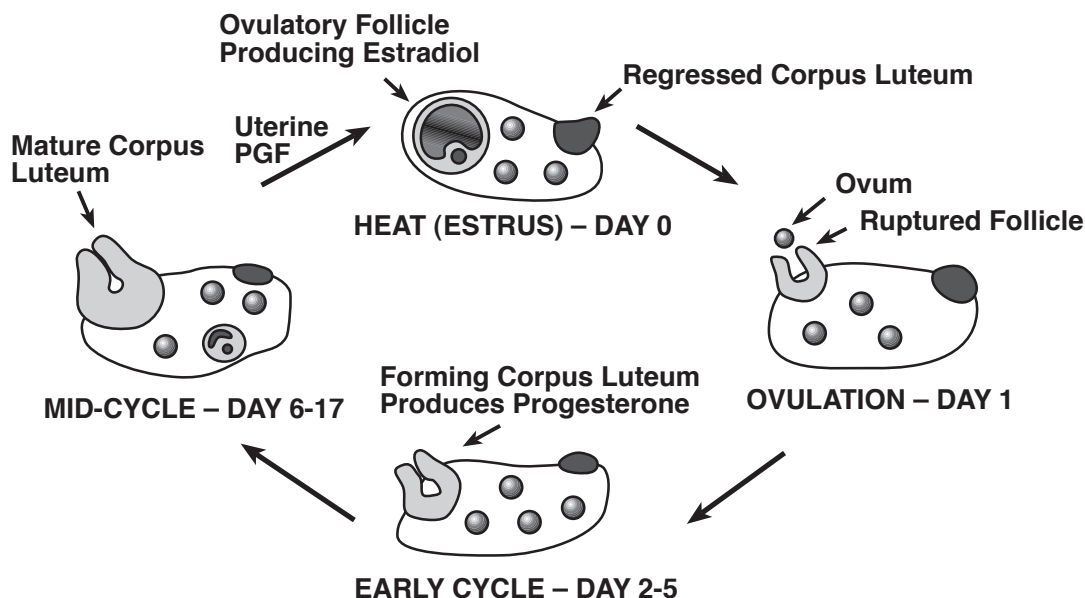
The formation, life, and demise of the CL results in a distinctive pattern of progesterone levels in the blood stream of cattle during the 21-day estrous cycle. This pattern, and that of PGF, is shown over an estrous cycle in Figure 2.

Figure 2. Pattern of Progesterone and PGF During the Estrous Cycle.

The increase in progesterone starting on Day 2 is the result of formation of the CL. Once the CL is fully functional (about Day 8), progesterone remains constant until Day 17. On Day 17, the production of PGF by the uterus causes the CL to regress quite rapidly, resulting in the fall in progesterone levels. **This action by PGF is a critical component of estrous control programs.** The ability to give PGF by injection, to regress the CL and remove progesterone from the blood stream, will in itself cause cattle to show heat two to five days later. The synchronized induction of regression of the CL in all animals is a fundamental part of essentially all estrous control programs. The key functions and necessary management of progesterone and PGF for estrous synchronization are outlined in Table 2. Some of the functions and/or management will be discussed later in this publication.

Table 2. Key Functions and Management of Progesterone and Prostaglandin $F_2\alpha$.		
Hormone	**Key Functions**	**Necessary Management**

Progesterone	Prevents estrus and ovulation, even at low levels. Influences growth of follicles. Exposure to progesterone is necessary before conception in anestrous females.	Synchronize decline in progesterone in all females by:
		  – Regression of CL.
		  – Removal of progestin from vagina or feed.

$PGF_2\alpha$	Induces regression of the CL and a decline in progesterone.	Inject at appropriate stage of the estrous cycle to regress the CL.

The manner in which ovarian follicles grow is much more dynamic than is illustrated in Figure 1. Ovarian follicles actually develop in a wave-like pattern (Figure 3). The discovery of this wave-like pattern of growth of ovarian follicles is relatively recent and has greatly heightened

our ability to control the estrous cycle for synchronization purposes. The capacity to control this pattern of follicle development is required for the success of timed insemination programs. Controlling this growth pattern is also beneficial to the precision of the timing of estrus when inseminating based upon detection of heat.

Figure 3. Waves of Follicular Development and Pattern of FSH.
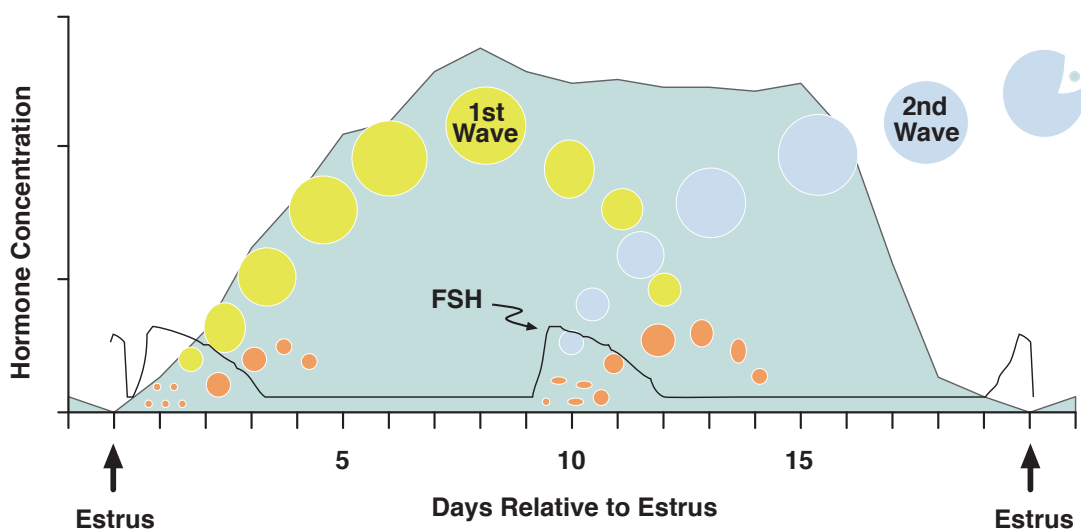
Ovarian follicles grow in what are normally referred to as "waves" during the estrous cycle. Most cattle have either two or three waves of follicles during each estrous cycle. The first wave for the following cycle starts around the time of ovulation. The second wave starts on approximately Day 10. In some cows, a third wave will start on Day 16 to 18 (not shown in Figure 3).

A wave consists of a group of small follicles that all begin to grow at the same time. The growth of each wave is initiated by a rise in FSH. As this group of follicles continues to grow, one of them becomes dominant over the others and suppresses the secretion of FSH.

The dominant follicle continues to grow, while the others in the group undergo follicle death, or atresia. The dominant follicle of the first wave (in females with two waves) and the dominant follicle of both the first and the second wave (in females with three waves) are destined to undergo atresia and be replaced by a new group of small follicles.

The reason that these dominant follicles undergo atresia is that progesterone prevents them from progressing to ovulation. Once the dominant follicle undergoes atresia, its suppressive effects on other small follicles and FSH are removed, which allows a new follicular wave to begin. In the two-wave example in Figure 3, the decline

in progesterone on Day 18, due to regression of the CL by PGF, permits this dominant follicle to grow to a stage that allows ovulation.

A fundamental component of all timed insemination protocols is to synchronize the waves of follicle development in all females, so that on a given day, all females have a dominant follicle that is of the same age and size. An injection of GnRH is used for this purpose. The key functions and necessary management of follicle waves for estrous synchronization are outlined in Table 3. Some of the functions and/or management will be discussed later in this publication.

Table 3. Key Functions and Management of Follicle Waves and FSH.		
Hormone	**Key Functions**	**Necessary Management**
Follicle Waves	Delivers ovum for fertilization. Provides a follicle to produce estradiol to cause estrus. Size at CL regression and growth rate influence time interval to estrus.	Synchronize time of initiation of follicle waves to permit: – Timed AI – Synchronized ovulation Synchronize follicle waves to prevent ovulation of: – Aged (persistent) or immature follicles
FSH	Stimulates start of each wave. Stimulates early growth of follicles. Is inhibited by the factors from the dominant follicle.	Induce ovulation of dominant follicles to permit a new wave at the appropriate time in response to FSH.

In addition to the ovum, another major product of the follicles is the hormone estradiol (Figure 4). Generally, the pattern of estradiol secretion follows the waves of follicle growth. Estradiol reaches its highest levels following the decrease in progesterone. The small pulses in luteinizing hormone (LH) that are released due to decreased progesterone cause the preovulatory follicle to produce higher levels of estradiol. The elevated estradiol acts on behavioral centers in the brain of cattle and causes estrus. An equally important function of the high levels of estradiol is to induce a surge release of GnRH from the hypothalamus, which in turn causes a surge of LH from the pituitary gland. The preovulatory surge of LH is directly responsible for initiating ovulation.

Figure 4. Pattern of Estradiol and LH During the Cycle.
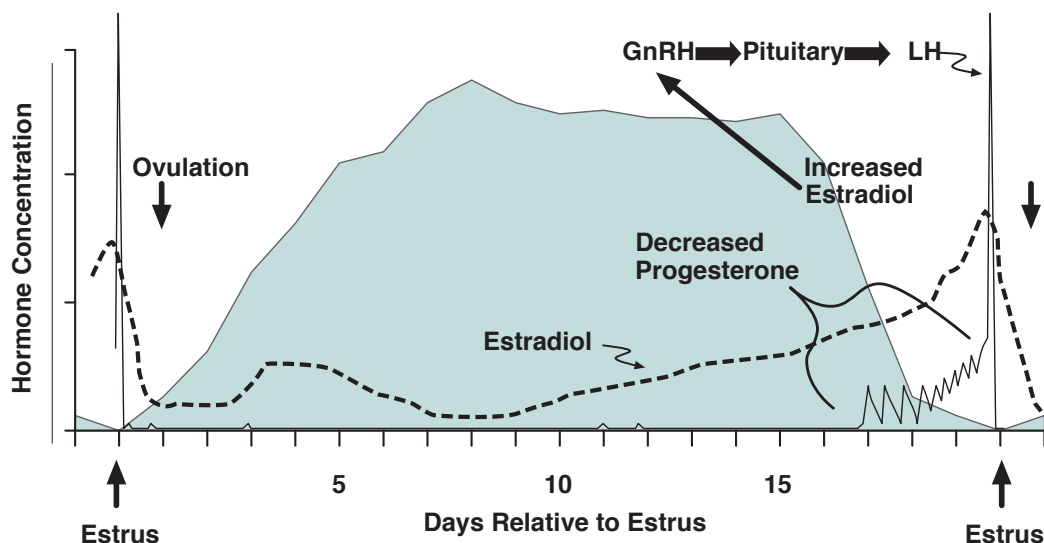
For estrous synchronization programs in which females are inseminated following detection of estrus, the sequence of increased LH pulses, increased estradiol, estrus, and the LH surge are allowed to progress spontaneously without intervention. In most timed insemination programs, an injection of GnRH is given to cause the LH surge, and thus ovulation, at a set time. In these programs, an interval of 48 to 72 hours after the decrease in progesterone is used to allow the earlier changes in LH and estradiol to occur. **Controlling the timing of the LH surge with an injection of GnRH is a fundamental part of most timed insemination programs.** The key functions and necessary management of estradiol and LH are outlined in Table 4. Some of the functions and/or management will be discussed later in this publication.

Table 4. Key Functions and Management of Estradiol and LH.		
Hormone	**Key Functions**	**Necessary Management**
Estradiol	Signal for the onset of estrus. Signal for the surge of LH.	Managed through control of follicular waves.
LH	Small pulses for final growth of preovulatory follicles. Surge causes ovulation. Inhibited by progesterone. Stimulated by GnRH.	Allow small peaks to grow follicles for 48+ hours after the decrease in progesterone. Induce an LH surge with GnRH to cause ovulation: – For timed AI. – To initiate a new follicle wave.

Combining all these key components and hormones of the estrous cycle presents a complex picture of the process that results in estrus and ovulation (Figure 5).

Figure 5. The Estrous Cycle in Cattle.
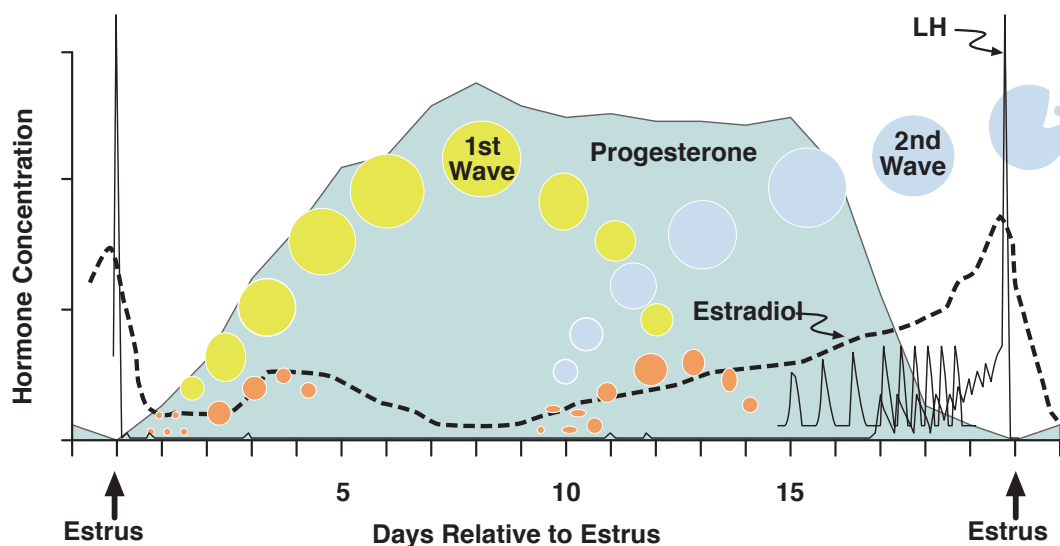
On a given day, when one chooses to initiate an estrus control program in a group of females, each animal that is cyclic is in a random and unknown stage of the estrous cycle. The task of the estrous control program is to modify these components and hormones to the extent that estrus and ovulation will occur in all animals at the same time. With the complexity of the estrous cycle, achieving this endpoint is one hurdle. However, the challenges for cattle producers who wish to synchronize estrus do not end here.

The second major obstacle to successful estrous control is that within all groups of postpartum cows and yearling heifers, there is a proportion of females that are either in postpartum anestrus (cows) or prepubertal anestrus (heifers). Anestrus is a normal occurrence and prevents females from conceiving before they have reached a reasonable proportion of their mature size (heifers) or at a time after calving that will substantially alter their annual calving interval (postpartum cows).

The proportion of females that are anestrus at the start of their annual breeding season can vary between herds from 20% to 70%, with this proportion dependent on many management factors that are discussed later. Heifers reach puberty at 12 to 15 months of age, and the duration of postpartum anestrus ranges from 25 to >80 days in postpartum cows. Figure 6 illustrates postpartum anestrus in terms of follicular development and progesterone concentrations in postpartum cows.

Figure 6. Postpartum Anestrus in Beef Cows.
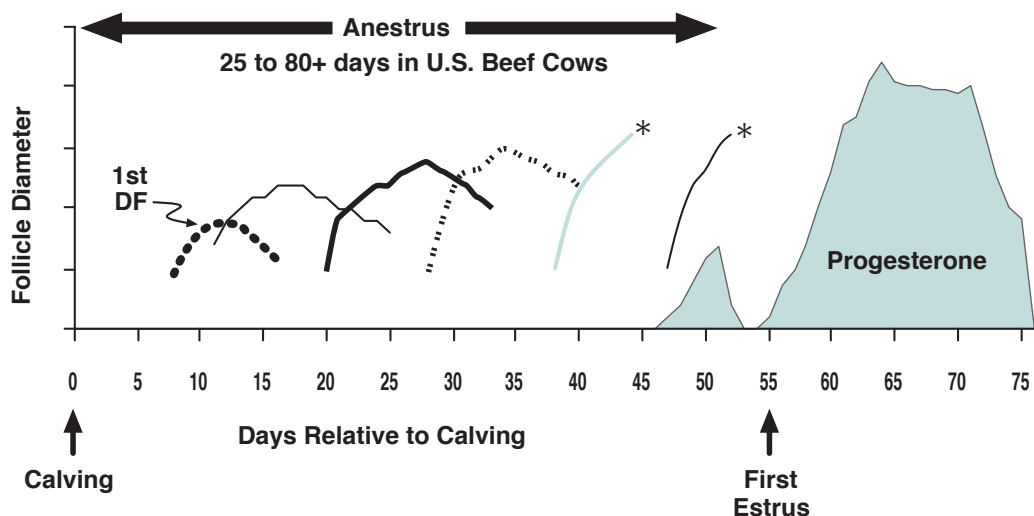
Notice in this example of a cow with an anestrous period of 55 days, that from calving until about Day 45, there is no progesterone in the animal's system. During this time, the female is not ovulating or forming a CL. She is not having estrous cycles, which is the basis for the term *anestrus.* There are, however, waves of follicular development occurring during this time.

The line labeled *1st DF* in Figure 6 indicates the growth and atresia of the first dominant follicle of the first wave after calving. Waves of follicle begin seven to 14 days after calving and continue up to, and through, the first ovulation after calving. The first ovulation after calving in this example occurred on Day 45 and is indicated by the asterisk at the end of the 5th DF.

Notice, however, that the increase in progesterone after this ovulation, and the interval to the next ovulation (2nd asterisk), is not 21, but only about 10 days. This *short cycle* is also a normal occurrence in more than 80% of postpartum cows at their first ovulation after calving and at the first ovulation in prepubertal heifers. Some cows (20 to 30%) will show heat at the beginning of the short cycle; however, cows that are inseminated or mate with a bull at this heat will not become pregnant.

The purpose of the short cycle is to provide a period of progesterone exposure before the first "normal" ovulation on Day 55. The short period of progesterone exposure is necessary for the next cycle to be a normal 21-day estrous cycle. In terms of estrous control systems designed to induce postpartum cows to ovulate, it is essential that the cow be provided with this short period of progesterone exposure before the estrus/ovulation at which insemination will occur. Conception rate of cows that do not have this period of progesterone exposure is thought to be 0%.

The capacity to initiate estrous cycles in anestrous cows is further complicated by the knowledge that all anestrous females are not equally responsive to treatments designed to induce heat. This variation among anestrous females is described by the concept of "depth" of anestrus (Figure 7).

**Figure 7. "Depth" of Postpartum Anestrus in Beef Cows.**
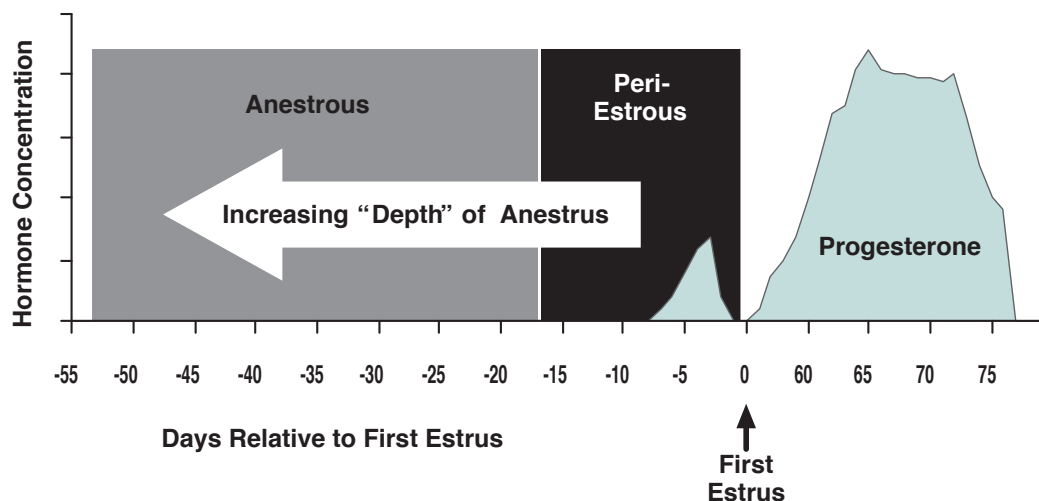
To explain this concept, the progesterone concentrations have been plotted relative to days from the first normal estrus in postpartum cows. Cows that are near the re-initiation of a normal estrous cycle (less than two to three weeks — peri-estrous) at the start of a synchrony program are believed to be very responsive to many of our current estrous control programs. Those females that are "deeper" in anestrus (more than two to three weeks before spontaneous resumption of estrous cycles — anestrous) are less responsive and require the more powerful of the estrous control systems to induce the onset of estrous cycles.

Within a herd, the proportion of anestrous cows that fall into each of these categories can vary widely, depending upon calving distribution, age of the female, genetics, nutritional program, and other management factors. Within the anestrous cows in a herd, prediction of which cows are peri-estrous and which are deeper in anestrus is difficult or impossible.

Since anestrous females usually represent a major proportion of a cow or heifer herd, and this proportion varies among years, it is critical that estrous control systems are available to induce anestrous cows to begin to cycle. The stimuli necessary to induce a majority of anestrous cows to cycle are outlined in Figure 8.

**Figure 8. Requirements to Induce Anestrous Cows to Cycle.**
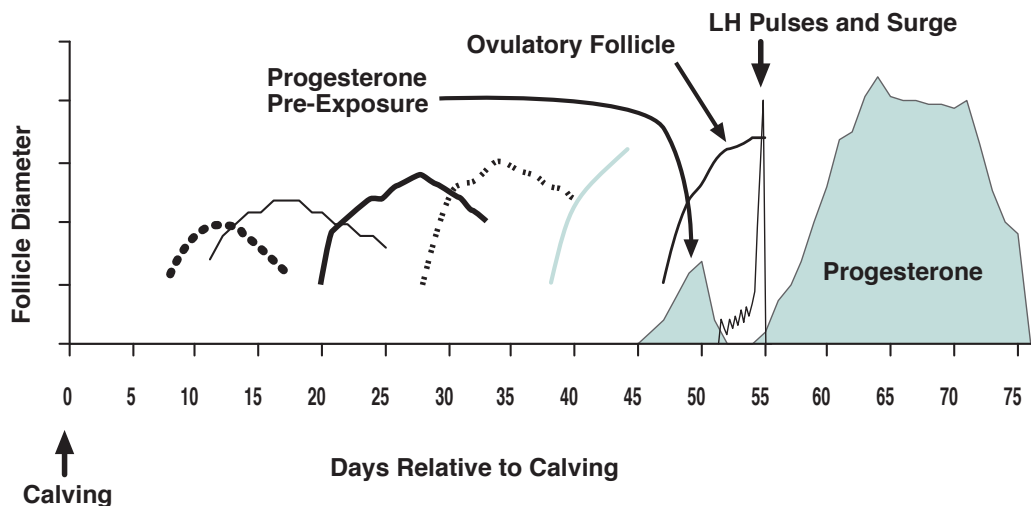
It has been established that pre-exposure to a short period of progesterone is required for two reasons. First, as mentioned earlier, pre-exposure is necessary to ensure that the subsequent synchronized heat or ovulation results in a fertile estrous cycle of normal length. Second, it has been shown that following treatment with progesterone (or a progestin) for five to 14+ days, a substantial proportion of cows will start to cycle on their own. Withdrawal of the progesterone will initiate the pulses of LH, followed by the surge in some cows.

This period of progestin exposure can currently be provided to the animal through two approaches. In one approach, the progestin is provided by giving an injection of GnRH to induce ovulation of a follicle and formation of a short-lived CL (Figure 9).

**Figure 9. Progesterone Pre-Exposure Using GnRH.**
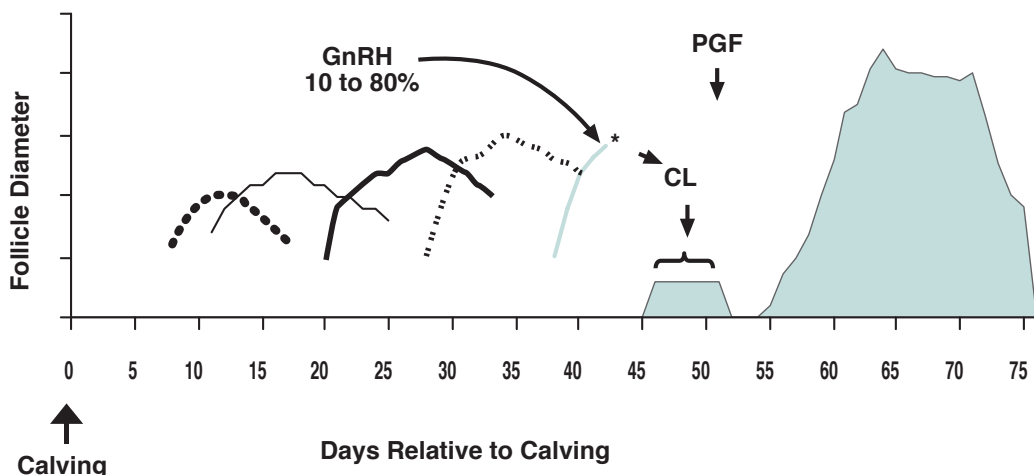
With this approach, cows are given an injection of GnRH to cause the existing dominant follicle to ovulate. The resulting CL is short-lived; however, this is irrelevant since the entire purpose of this is to provide a short period of progestin exposure. The limitation of this approach is that within groups of anestrous cows, the response in terms of ovulation can vary from 10 to 80%. It is presumed that in herds with many anestrous cows in **deep** anestrus, the response to GnRH is low, and in herds with most anestrous cows in the peri-estrous category, the response is high.

The alternative approach to using GnRH to provide progesterone pre-exposure is to administer a progestin directly, either through the feed (MGA) or with the intravaginal insert (CIDR). This is a more predictable method, as delivery of progesterone is 100% in all females.

The number of cows that ovulate following the withdrawal of the progestin can be increased substantially by providing a stimulus for the surge of LH. This is achieved in some current systems with an injection of GnRH two to three days after withdrawal of the progestin (Figure 10).

Figure 10. Use of Progestin and GnRH to Induce Ovulation.
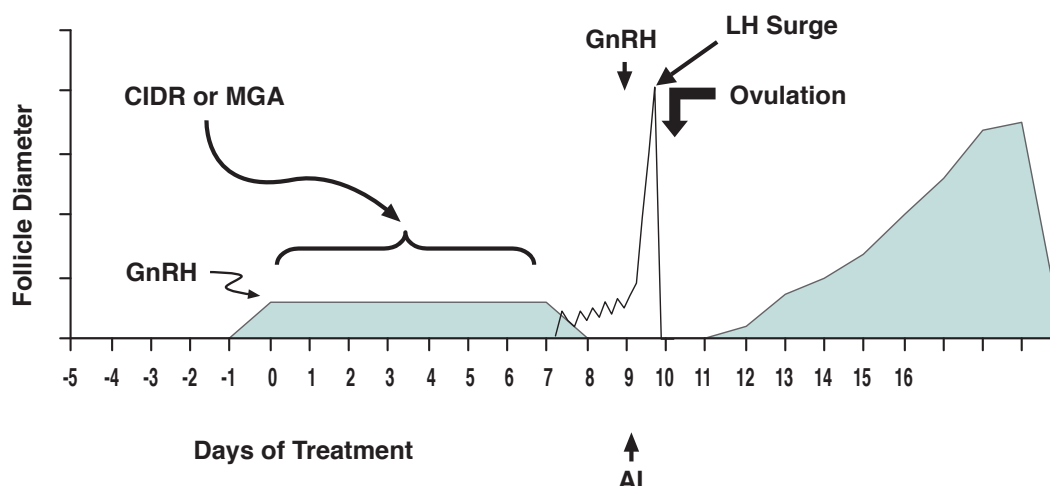
The sequence of progestin pre-exposure (with either GnRH, a CIDR, or MGA) followed two to three days after the progestin decreases by an induced surge of LH (with GnRH) is the most powerful tool available to U.S. producers to induce anestrous cows to resume estrous cycles or heifers to reach puberty. With this sequence, females can be inseminated at the induced ovulation on Day 9 or 10 with a reasonable expectation for pregnancy.

The challenges of estrous synchronization should be relatively obvious as one considers the preceding pages. On a given day in the spring (or fall), the objective is to start an estrous control program on a group of females that includes cyclic females in all stages of the estrous cycle and anestrous females in varying depths of anestrus. In most herds, it is difficult to identify into which of these categories individual females fit. Therefore, if synchronization of the entire herd is the goal, a single sequence of

treatments, or perhaps one designed for cows likely to be cyclic and another for cows likely to be anestrus, is required to cause all of these animals to show estrus and/or ovulate on a single day for timed AI, or over a three- to five- day period for insemination based upon estrous detection. Fortunately, the pace of discoveries in reproductive physiology and the development of new technologies have made this seemingly insurmountable task achievable.

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Production and Physiological Requirements for Estrous Control

The extent to which producers will use a technology to synchronize estrus is dependent upon the efficacy of the treatment. Effectiveness can be defined in several ways, and different producers would have different goals that they wish to achieve. For example, the capacity for timed insemination rather than mating based on estrus detection is of paramount importance to some producers but less critical for others. As a second example, some producers may feel it is essential to include the entire herd in a synchrony program, while others may choose only to include a sub-group of females (e.g., cows that calved in the first 30 days of the calving season).

For systems in which the entire herd will be included in the synchronization program, the endpoints listed here represent viable production goals.

1. The system of synchrony should enhance the reproductive performance of the cow herd as measured by average day of conception during the breeding season, rather than simply concentrating the times that AI will take place.

2. The system should be effective in all cows and heifers within the herd. Onset of estrus should be induced in a majority of anestrous females, and the synchronized estrus in cyclic females must be of a level of fertility equal to or greater than a spontaneous estrus.

3. More than 50% of the herd should become pregnant to AI over a maximum of three days or to a timed insemination protocol.

4. The system should minimize cattle handling, use treatments that are easy to administer, and be of reasonable cost while attaining the previously stated goals.

5. A hidden requirement that is essential to achieve the stated goals is that the herd must be adequately managed from both a reproductive and nutritional standpoint. Cows must be maintained in an adequate body condition; a defined breeding season is requisite; the first-calf heifers should calve before the cowherd or early in the main calving season; and appropriate replacement heifer selection and management is necessary.

In order to achieve the production endpoints outlined previously, three key physiological requirements must be met by the estrous control system.

1. A synchronous decline in progesterone (or exogenous progestin) must occur in all animals as a result of luteal regression or withdrawal of a progestin source.

2. Adequate stimulus must be provided to the reproductive system of anestrous females to induce ovulation in a majority of females in this reproductive classification.

3. Ovarian follicle growth must be managed to:
    a. Ensure that those follicles that ovulate, yield oocytes of normal fertility.
    b. Ensure that the stage of follicular growth is approximately equal at the time of the progestin decline to permit precise timing of estrus and/or ovulation (timed AI).

The current understanding of function of the reproductive system in cattle, the impact of

various treatments on this system, and new technological advances have made possible the development of synchronization systems that meet these production and physiological requirements. In situations in which a sub-group of females within a herd is treated, it may not be essential to meet all of these requirements. However, with this approach it is typical to expect a greater or lesser estrus response and conception rates, depending on which females have been excluded from the synchronization program.

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Mathematical 'Laws' of Estrous Synchronization

As one considers the implementation of estrous control programs and decides to compare and contrast various systems, there are a few simple "laws" or "facts" that are often overlooked.

Law No. 1 — There are 365 days in a year; gestation length in cattle is approximately 285 days; and cows are expected to produce a calf on an annual basis.

From this statement, it can be calculated that in order to calve a herd at the same time each year, there will always be approximately 80 days from the start of the calving season to the start of the next breeding season (365 – 285 = 80). Thus, the first cows to calve in a herd will be about 80 days after calving when the next breeding season starts. The later a cow calves, the fewer days postpartum she will be at the start of the breeding season and the greater the likelihood that she will be anestrus.

As an example, if the breeding season for the previous year was 60 days, cows conceiving on the last day of that season will calve approximately 20 days before the start of their next breeding season. If the previous breeding season was 90 days in length, cows may still be calving when the breeding season for the current year is started. This relationship cannot be changed, unless one decides to calve later in each successive year.

This law stresses the importance of controlled breeding seasons of 60 days or less, especially if a goal is to synchronize the entire herd at the start of each breeding season.

The second point that should be derived from this is that the synchrony system should be as short as possible. In most herds, there will not be 20+ days from the end of calving to the start of breeding, thereby limiting the desirable length of a synchronization system.

Law No. 2 — The pregnancy rate for a group of animals in which estrous synchronization and AI are used is a function of two factors: Pregnancy Rate = Submission Rate x Conception Rate.

Again, this seems simple. However, it is quite easy to get distracted by what the true endpoint should be for an AI program. In most cases, the desire is to get as many cows pregnant by AI at the start of the breeding season then either to try to AI the returns approximately 21 days later and let the bulls clean up, or to simply let the bulls take over shortly after the synchronization period.

If the factor of conception rate is first considered, the easiest way to maximize this factor within a herd is to apply a synchronization system to all animals and inseminate only those that show estrus. If cows have the capacity to grow a follicle to the level that it will cause the cow to come into heat, the conception rate will be determined primarily by the skill of the individuals who are detecting estrus, the AI technician, semen quality, and the inherent fertility of the cowherd. In this case, you are not "making" cows show heat; you are just grouping their expression of heats into a similar time.

It is critical to realize that all females will not show heat with any of the systems available in the United States. The losses in terms of animals not "submitted" for breeding can be attributed to three primary categories:

1. Cows that show heat but are not observed.

2. Cows that ovulate but do not show outward signs of heat.
3. Cows that are anestrus, or are ineffectively synchronized, that do not ovulate or show heat during the synchrony period.

If the approach is taken to only inseminate cows that show estrus in a whole-herd synchrony program, it would not be unusual for the submission rate to range from 30 to 80%. If we do the math for a herd with a 50% estrus response and a 70% conception rate, 35% of the herd will be pregnant to AI during the synchronization period. This is unacceptable, or marginally acceptable, to most producers.

As another example, if only 60% of the herd is enrolled into a program (e.g., exclude cows that calve in the second half of the season, two-year-old cows, etc.), submission rate for this sub-group will likely be as high as 80+%. However, the math still shows that submission rate = 48%

(80% detected of 60% of the herd). Therefore, with a conception rate of 70% and a submission rate of 48%, pregnancy rate for the herd is 34%.

In terms of submission rate, it is very easy to make this equal 100% if timed AI is used. With this approach, all females are inseminated, regardless of whether they show estrus. If appropriate control of the timing of ovulation is in place, and mainly animals from categories 1 and 2, as explained previously, are added to the insemination group, conception rate would not be expected to decline substantially, and the whole-herd pregnancy rate would increase.

However, if there were a large number of cyclic females that were not synchronized, or anestrous females that did not ovulate (category 3), these animals will not conceive to a timed insemination, and the conception rate could decline considerably. The two examples outlined in Table 5 are for a herd in which 50% would have been detected in heat without timed AI.

Table 5. Influence of Herd Response Category on Pregnancy Rate to Timed AI.						
Sub-Group of Herd	Example 1			Example 2		
	No. AI	Conceive %	No. Preg.	No. AI	Conceive %	No. Preg.
Would have been detected in heat	50	65%	33/50	50	65%	33/50
Ovulating correctly but not in heat	40	60%	24/40	10	60%	6/10
Not synchronized and/or ovulating	10	0%	0/10	40	0%	0/40
Total	100	57%	57/100	100	39%	39/100

Considering Example 1, this illustrates how timed AI can be beneficial to pregnancy rate if it increases submission rates of cows that are potentially fertile, but not detected or showing heat. Example 2, however, demonstrates that females must be successfully synchronized and

induced to ovulate (in the case of anestrous cows) if this approach to increasing submission rate is to be profitable. In herds with a sizeable proportion of anestrous females, synchrony systems that induce these females to initiate cycles are imperative for success.

Law No. 3 — The overall conception rate to a synchronized estrus will decrease as the proportion of the herd that is inseminated increases.

This statement is somewhat redundant with Law No. 2 but deserves mention in itself. Some synchronization programs are quite powerful and effective in inducing a potentially fertile ovulation in a majority of anestrous females.

With these systems, cows that normally would have shown estrus one to five+ weeks after the start of the breeding season are induced to ovulate on the first day of the breeding season and are inseminated. This provides them an opportunity to conceive early, but typically their conception rates are lower. This should not be surprising as we are forcing their reproductive system to function before it is fully prepared to function spontaneously. In a herd with 50% of the females in anestrus, an aggressive synchrony program that allows one to inseminate these females, at a 40 to 50% conception rate, would be considered a success in many cases. The alternative is no synchronized pregnancies in 50% of the cowherd. Conception rates can vary considerably and are dependent upon technician proficiency and fertility of both the semen and the cowherd. It is important to have realistic expectations. Excellent conception rates are typically about 75%.

A related issue is that one can make any synchronization system available appear to be tremendously effective by avoiding the high-risk animals within a herd. Often excellent results are reported for select groups of females (usually mature cows that calved in the first three to five weeks of the calving season). Essentially any synchronization system available can make a high proportion of these animals show heat and result in or approach excellent conception rates, because they are all cyclic or peri-estrous. See Law No. 2 to evaluate the true impact of this approach on reproductive efficiency of the cowherd.

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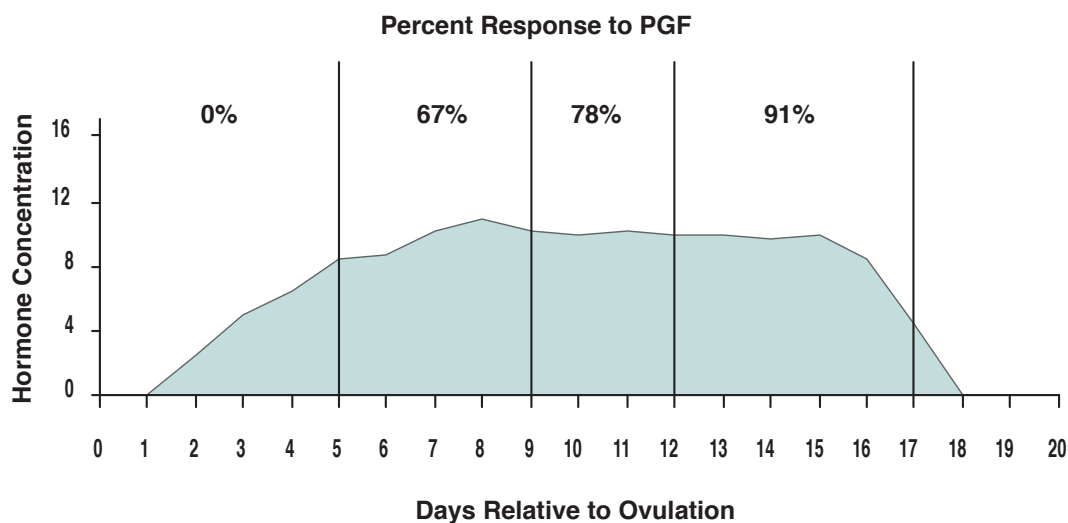2027 Coffey Road
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Systems of Synchronization Using Prostaglandin $F_2\alpha$

Introduction

The most widespread approach to estrous synchronization in the United States has been through the use of prostaglandin $F_2\alpha$ (PGF). Prostaglandin $F_2\alpha$ regulates a female's estrous cycle by causing regression of the CL. An injection of a synthetic PGF (see Table 1) will mimic natural PGF release to cause CL regression. Synchronized regression of the CL will synchronize a decline in progesterone and result in the final growth of the dominant follicle to produce estradiol and behavioral heat. Females with a mature CL on their ovaries when they receive an injection of PGF will usually exhibit heat two to five days later. Thus, in order for PGF to be effective, females must be cyclic and in a responsive phase of the estrous cycle. The responsiveness of cows to PGF at various times in the cycle is diagrammed in Figure 11.

Figure 11. Stage of the Estrous Cycle and CL Regression with PGF.

Percent Response to PGF

If PGF is to be used exclusively to synchronize estrus, it is necessary to ensure that most cyclic females have a mature CL that is susceptible to regression by PGF. For optimal responses, it is helpful if only cows that are likely to be cyclic are enrolled in the synchronization program.

Prostaglandin $F_2\alpha$ will not regress an immature CL (Days 1 to 5), and the effectiveness of this treatment increases with each subsequent day of the cycle after Day 5. Prostaglandin $F_2\alpha$ also has no effect after the CL has started to regress (Day 17+), but cows between Days 17 to 20 of their estrous cycle are coming into heat over the next one to four days anyway and appear to respond to the injection. Anestrous cows and prepubertal heifers will not respond to an injection of PGF since no CL exists. If they represent a major portion of the herd, response rates could be quite low.

With PGF systems, control of follicular waves is not provided, and cows must be inseminated following detection of estrus, not to a timed insemination.

Four PGF programs are being used to synchronize estrus in cattle. Two of these programs require two injections of PGF, and two require a single injection. Fertility of cows at an estrus resulting from an injection of PGF is similar to that of females that show heat spontaneously.

One Injection of PGF with Insemination After PGF

Inject all cows, check heat, and inseminate all cows 12 hours after detection of standing heat (Figure 12). With a single injection of prostaglandin, ~70% of the cyclic cows would be expected to display heat (those on Day 6 or greater of the cycle at injection) during the next four to five days. The percentage of the animals injected that are anestrus can have a major influence on response rates. For example, if 100 females are injected, and only 50 are cyclic, the estrus response would be 35% (70% of 50 cyclic females/100 females injected).

Figure 12. One Injection PGF Protocol.
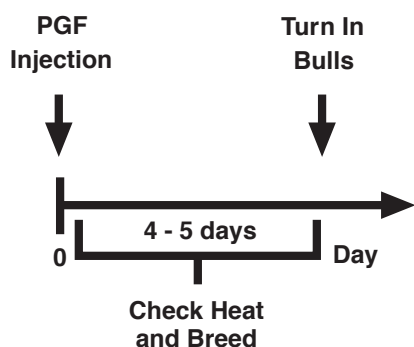
Two Injection PGF Programs

The two injection programs for synchronization with PGF are designed to increase the proportion of females with a CL that is responsive to regression with PGF. Traditionally, the recommendation was that two injections of PGF be administered 11 days apart, but recent data suggest that a 14-day interval is more effective.

With the first PGF injection, ~70% of the cyclic cows would be expected to display heat (those on Day 6 or greater of the cycle at injection) during the next four to five days. Those animals that were not responsive to the first injection (i.e., on Days 1 to 5 of the cycle at the first injection) would respond to the second injection. Also, cows in heat after the first injection would be on Day 6 or greater of their next estrous cycle and would be expected to show heat a second time, following the second PGF injection.

With all systems that use PGF, another PGF injection could be added to any protocol (11 to 14 days later) in cows not inseminated to provide another opportunity for AI. Remember though, if cows did not initially respond because they were anestrus, an additional PGF injection will be of no benefit.

Program 1: Initially, an injection of PGF is given to all cows. Two to five days after the first injection, ~70 % of the cyclic females should be in heat. Females detected in heat are inseminated 12 hours later (Figure 13). With this program, animals not inseminated after the first PGF receive a second PGF injection 11 to 14 days later and are inseminated 12 hours after detection of heat.

Do not give the second PGF to cows that have been inseminated after the first PGF; this will terminate that pregnancy.

Program 2: This approach is similar to Program 1, except that no inseminations are performed

after the first PGF injection, and all females receive the second PGF. This sequence should, theoretically, synchronize estrus in essentially 100% of cyclic cows within two to five days after the second PGF. In application, some cows that display heat after the first injection fail to do so after the second PGF, and synchronization responses of 75 to 85% after the second PGF are common with this protocol.

With either program, the number of anestrous cows that are treated will influence estrus responses in a manner similar to that described for the single injection system.

Figure 13. Two Injection PGF Protocols With Breeding After Both (Program 1) or Only After the Second Injection (Program 2).
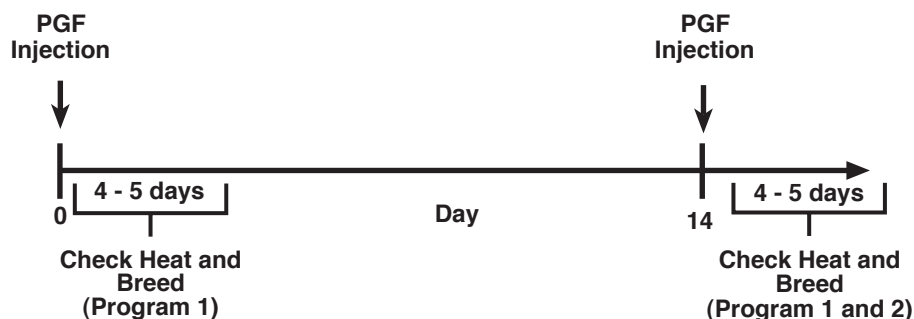

One Injection With Inseminations Before AND After PGF
Check heat and inseminate all cows detected in estrus for the first five days of the breeding season. Inject all females not previously inseminated with PGF on Day 5 and inseminate 12 hours after detection of heat (Figure 14). By inseminating cows in heat for the five days before PGF, no cows that receive PGF will be on Day 1 to 5 of the estrous cycle. Thus, all cows that are cyclic should show estrus within five days after the PGF injection. This is the most popular protocol that uses only PGF to synchronize estrus and can result in more than 90% of cyclic cows being bred during the first 10 days of the season.

Figure 14. One PGF Injection With 10 Days of Heat Detection.
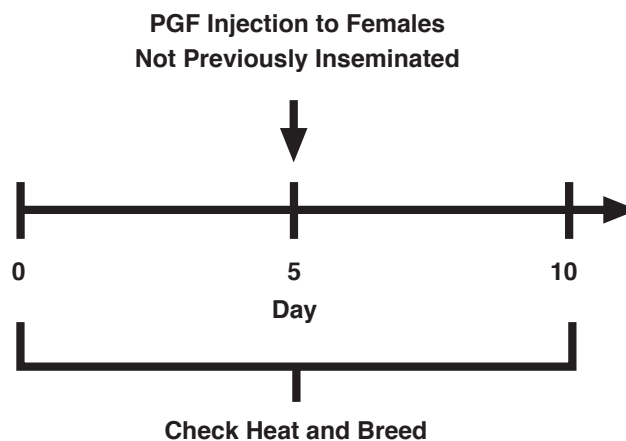
**PGF Injection to Females
Not Previously Inseminated**

0   5   10

Day

Check Heat and Breed

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Systems Using Prostaglandin $F_2\alpha$ and a Progestin

Introduction

While the use of PGF is included in essentially every program cited, some programs have been developed that incorporate the use of a progestin with PGF. The addition of a progestin addresses two aspects of estrous control. Most importantly, providing a progestin will induce some prepubertal heifers and anestrous cows to begin cycling and to have a normal-length estrous cycle following the first ovulation. Through this action, this sub-group of cows within a herd has an opportunity to be inseminated at the start of the breeding season. A second advantage is that since progestins prevent animals that are cyclic from showing heat, when used they typically increase the proportion of animals with CL that are responsive to PGF at the time this hormone is injected.

Progestins are an extremely valuable tool for estrous synchronization; however, they must be used appropriately to avoid negative effects on fertility that are inherent to their use. The progestins that are available for use in the United States effectively prevent estrus and induce anestrous cows to cycle, but they can cause inappropriate follicular growth and reduced fertility if used indiscriminately.

Abnormal follicular growth occurs when estrus is inhibited by progestins in the absence of a CL and the progesterone it normally produces. In this situation, the dominant follicle does not undergo atresia and persists on the ovary (persistent follicle). When the progestin is withdrawn, the persistent follicle ovulates, and the ovum released is of lowered fertility (Figure 15). The reduction in fertility is most evident in cattle that start a progestin treatment late in the estrous cycle, and the longer we give a progestin to a group of cyclic females, the greater the reduction in fertility.

In Figure 15, the dominant follicle of the second wave would be expected to ovulate on Day 21 with no intervention. The progestin prevents this, and the follicle grows to an abnormal diameter and age. After withdrawal of the progestin on Day 24, the persistent follicle ovulates, and fertility is low.

In systems that use progestins, three approaches are taken to avoid this reduction in fertility. The first approach is to avoid the problem and wait until the next heat period to inseminate. The second option is to use a short period of progestin exposure to minimize the reduction in fertility. The third method is to administer a treatment at the start of the synchronization treatment that will reset follicular growth and prevent the development of persistent follicles. Each of these options is incorporated into systems described here.
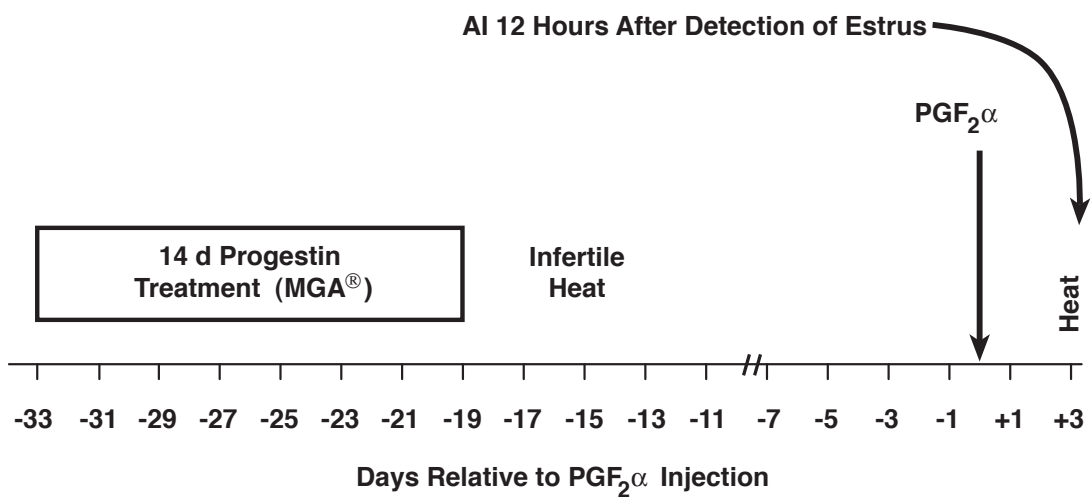
Figure 15. Persistent Follicle Formation with Progestins.
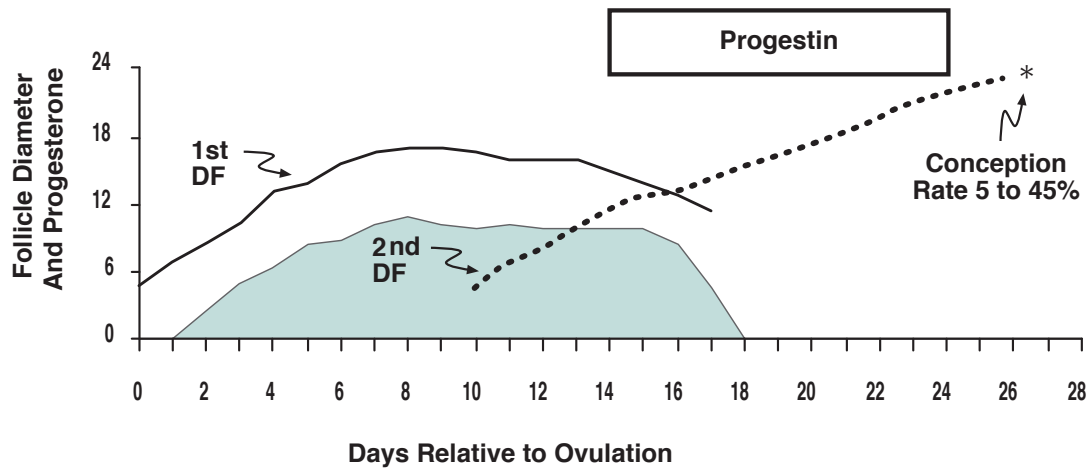
Melengestrol Acetate (MGA) and PGF

One system of estrous synchronization uses the progestin, MGA, and PGF (Figure 16).

Figure 16. MGA-PGF for Heifer Synchronization.

In this system, MGA is fed at 0.5 mg/head/day for 14 days. Feeding MGA for 14 days prevents cyclic females from showing heat even if their CL regresses, until the MGA is removed from their feed. Essentially all cyclic females and some anestrous females will exhibit estrus within a week after withdrawal of the MGA. This is a subfertile heat, with many females ovulating a persistent follicle. They should not be inseminated at this estrus.

A single injection of PGF, administered 17 to 19 days after the MGA has been withdrawn, will regress the CL that developed following the infertile heat. Most females will show estrus 48 to 72 hours after PGF and can be inseminated 12 hours after detection of estrus. The most common approach is to check heat for five to seven days and inseminate upon detection. Alternatively, timed AI of all females, or just those that have not yet displayed heat by 72 hours after PGF, can often result in acceptable pregnancy rates.

There are two major reasons why this is an effective system, particularly with heifers. First, the 14-day feeding period of MGA will group the heats in cyclic females and induce onset of cycles in some prepubertal heifers. Variable proportions of the anestrous females will be induced to ovulate, probably dependent upon their distribution between peri-estrous and anestrous status (see Figure 7). Secondly, the 17- to 19-day waiting period was carefully chosen in order to ensure that most females would be in the latter stages of the estrous cycle (after Day 12) when PGF was given. The effectiveness of PGF to cause regression of the CL is highest at this time

(refer to Figure 11). It is not uncommon for estrus response rates to exceed 80% and conception rates to be 70% or greater when using this system on heifers. The 19-day interval between the last day of feeding MGA and PGF yields a more precise estrous response.

An important consideration of this system is to ensure that all females consume MGA on a daily basis. If consumption is inadequate, females will show estrus during the MGA feeding period, and the initial synchronizing effect of the MGA will be lost. A disadvantage of this system is the length of time between initiation of feeding MGA and the start of the breeding season (31 to 33 days). With yearling heifers, this can be accommodated with careful planning.

In postpartum cows with an annual calving interval, it is much more difficult to implement this type of system as there are not typically 31 to 33 days available between calving and the start of the next breeding system (see Law No. 1). A concern with this approach in postpartum cows is that some data suggests that there is an increased incidence of twinning with this system. An adaptation of this approach that is used with postpartum cows is described later.

Intravaginal Progesterone-Releasing Insert (CIDR) and PGF

A second progestin-PGF system involves the use of progesterone, delivered by means of a CIDR, and PGF. The sequence of treatment for this system is described in Figure 17.

Figure 17. CIDR$^{\circledR}$ and PGF Synchronization System.
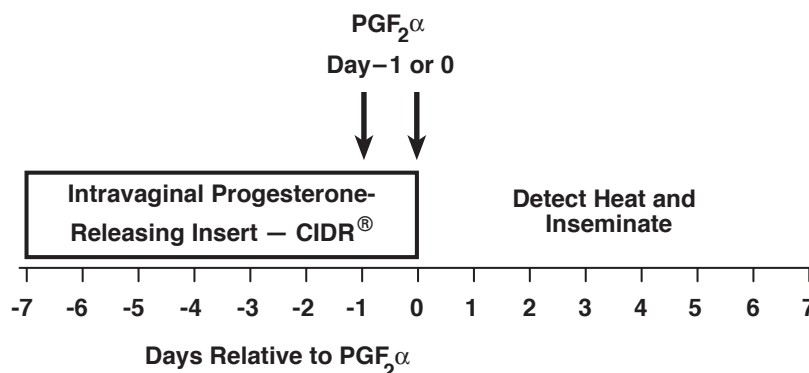
With this system, the CIDR is inserted into the vagina of the female for seven days. An injection of PGF is given either one day before or on the day of CIDR withdrawal. Females are inseminated based upon detection of estrus during the three- to five-day period following treatment. This system will effectively synchronize estrus in a large proportion of cyclic females since treatment for seven days with the CIDR prevents animals from being in the early stage of the cycle and unresponsive to regression of the CL by PGF.

Variable proportions of the anestrous females will be induced to ovulate and show heat during the synchronization period. This variation is probably the result of the distribution of animals in the peri-estrous and anestrous categories (see Figure 7). Some data suggest that a greater proportion will ovulate than will show heat, and thus some of the anestrous females will display their first heat approximately 21 days later.

A putative disadvantage of this system is that the potential exists for persistent follicles to develop in cyclic females that are in the latter stages of their estrous cycle when the treatment is initiated. However, data to this time indicates fertility is normal at the synchronized estrus in yearling heifers or postpartum cows receiving this synchrony system. Re-use of CIDRs in this system for a second or third time delivers progesterone at a lower level and will cause development of persistent follicles in some females.

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GnRH-Based Systems of Estrous Synchronization

Introduction

None of the systems described up to this point have included treatments that address the physiological requirement of managing follicle growth to ensure that follicles will ovulate ova of normal fertility and to standardize stage of follicular growth to cause the timing of estrus to be more precise and/or synchronizing ovulation for timed AI. Each of the preceding systems permits the females to show heat based upon spontaneous follicle growth, and they are inseminated accordingly. As an example, the expected response for three animals injected with PGF on different days of the estrous cycle is diagrammed in Figure 18.

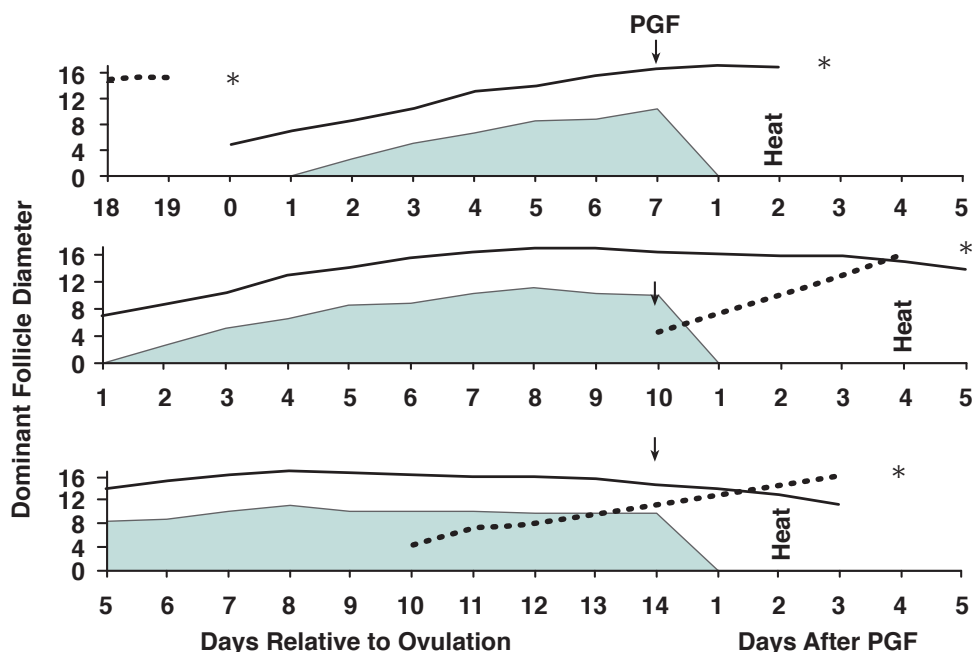**Figure 18. Estrus and Ovulation After PGF by Stage of the Cycle.**

Figure 18 describes a typical response in terms of follicle growth, estrus, and ovulation following injection of PGF on Days 7, 10, and 14 of the estrous cycle. In each case, progesterone (shaded area) declines within 24 hours. For the example of PGF on Day 7, the dominant follicle of the first wave (solid line) is at near maximal size at the time of PGF. This follicle will rapidly produce adequate estradiol levels to cause heat two days after PGF and ovulation the following day.

In contrast, with injection of PGF on Day 10, the first wave follicle has undergone atresia, and the dominant follicle of the second wave is immature. The interval of time it takes for the immature follicle to grow large enough to produce sufficient estradiol and cause estrus is four days. With injection of PGF on Day 14, the dominant follicle of the second wave is intermediate in size, and estrus occurs three days after PGF. This variation is normal and is the result of the normal pattern

in which follicles grow. This does not present a problem for synchrony systems based entirely upon heat detection to determine the time of insemination. However, the use of GnRH provides a means to standardize the pattern of follicular growth in a majority of animals. This is advantageous to avoid development of persistent follicles and for estrous control systems in which an injection is used to synchronize the time of ovulation for timed AI.

When GnRH is used for this purpose, it is typically given the first day of a synchronization system to program emergence and growth of the subsequent wave of follicles through inducing luteinization and/or ovulation of dominant follicles in the ovary. Through removal of the existing dominant follicle, the emergence of a new wave of follicles approximately two days later is achieved in most females (Figure 19).

Figure 19. Influence of GnRH to Synchronize Dominant Follicles.
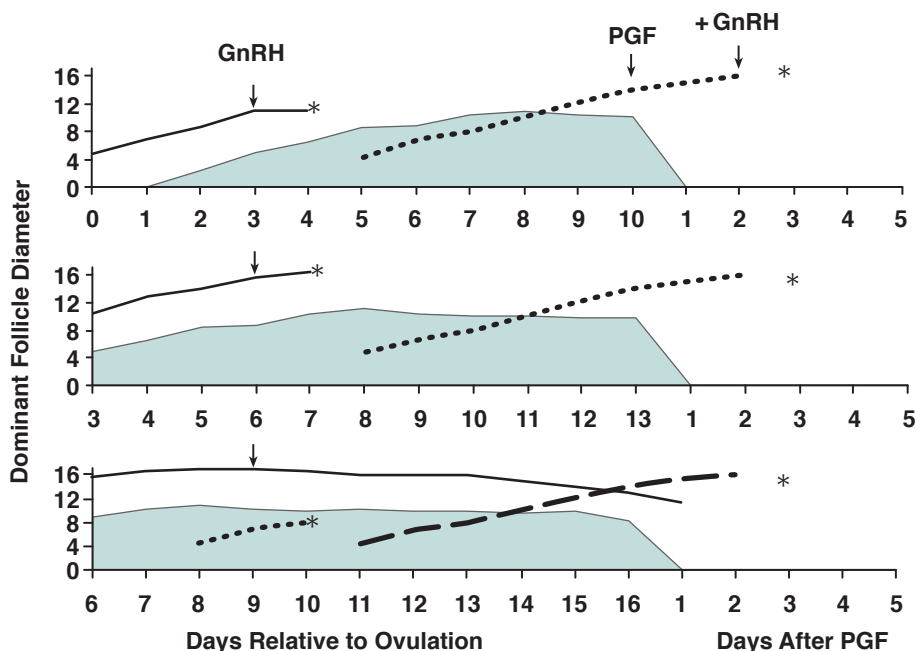
In Figure 19, examples of the influence of GnRH on follicle growth when given on Days 3, 6, or 9 of the estrous cycle are shown. On Day 3 and 6, the largest follicle of the first wave is dominant. On Day 9, the second wave of follicles has emerged in this example. Regardless of stage at the time of GnRH, the key effect of the GnRH is to stimulate emergence of a new wave of follicles two days later in all females. As a result of this action, the dominant follicle present on the day of PGF is of similar age and diameter in all cows. If females are allowed to show heat spontaneously after PGF, the timing of estrus will be less variable than with the PGF example in Figure 18. The +GnRH treatment that is shown is a second GnRH that can be used to synchronize ovulation for timed AI. Since all females have follicles of similar diameter, the appropriate time to make

these follicles ovulate in all cows can be chosen. It would not be possible to pick a single time to induce ovulation in the PGF example in Figure 18.

In postpartum cows, the effectiveness of GnRH to cause the response described in Figure 19 increases with diameter of the dominant follicle that is present. For example, in this illustration, GnRH would be effective in nearly 100% of cows on Day 6 of the cycle, when a large dominant follicle is present. On Days 3 and 9 of the cycle, a proportion of cows would not have a follicle that would ovulate in response to GnRH. This variation in response is most detrimental in cows that do not have a dominant follicle on Days 15 to 17 of the estrous cycle. This sub-group of cows will be in heat five to seven days after GnRH following the impending regression of the CL. Fertility is normal, but these females will not be synchronized with the rest of the cows. Some of the systems described later account for these "early heats." The effectiveness of GnRH to program follicle growth in yearling heifers is less than can be achieved in postpartum cows. It

is generally accepted that GnRH-based systems are more effectively applied in postpartum cows than yearling heifers. However, GnRH-based programs that incorporate a CIDR (described later in the document) have been shown to be effective in yearling heifers.

When using GnRH in whole herd synchrony, the other important action of this hormone is to induce ovulation in some anestrous cows, thereby providing a source of progestin pretreatment. The value of this effect is described in an earlier section (Figures 9 and 10).

A series of GnRH-based systems of varying complexities has been developed. The simplest programs are designed for use primarily in cyclic females with insemination based on detection of estrus. Others have been developed in order to support the use of timed AI and/or to induce varying proportions of anestrous females to ovulate. The various treatments that can be used in combination with GnRH are described in Figure 20.

Figure 20. GnRH-Based Systems in Postpartum Cows.
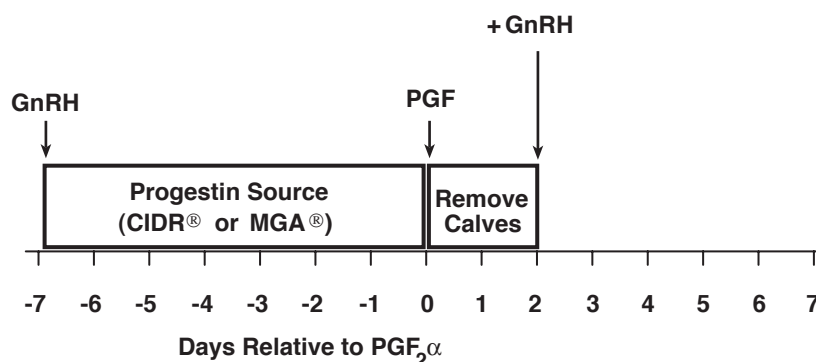
In Figure 20, all possible treatments that could be used in combination with GnRH are indicated. The initial GnRH injection (Day –7; GnRH) is used to program follicle growth in cyclic females and to induce ovulation (to provide progestin pre-exposure) in anestrous females. The PGF (Day 0) induces regression of CL that are present to induce a decline in progesterone. The second GnRH given on Day 2 to Day 3 (+GnRH) will induce ovulation of dominant follicles that have been pre-programmed by the first GnRH treatment. Administration of a progestin from Day –7 to Day –1 or 0 suppresses the "early" heats in cyclic cows and provides progestin pre-exposure to the anestrous females. "Remove calves" denotes separation of the calves from their dams for 48 hours. This withdrawal of the suckling stimulus provided by the calf will aid in inducing anestrous cows to ovulate. These various treatments can be used as needed to meet the objectives of the synchrony program.

GnRH – PGF System: This combination represents the simplest GnRH-based system and involves the GnRH treatment followed seven days later by the PGF treatment (Figure 20). A common name that is often used for the GnRH – PGF system is *Select Synch.* Some cows (~8%) will exhibit estrus up to 36 hours before PGF. The "early" heats are fertile, and cows can be inseminated 12 hours after detection. The PGF treatment is not necessary in "early" cows that have already exhibited estrus but will not compromise the pregnancy, if given. The peak estrous response will occur two to three days after PGF with a range of Days 1 to 5. With this system, a minimum of five days of estrous detection after PGF and two days preceding PGF is required to detect most heats. A large proportion of cyclic females will be in estrus during this seven-day period. This protocol will initiate estrous cycles in some anestrous cows although results can be unpredictable (Figure 9). The GnRH – PGF system is most effective if used on cyclic cows, or cows that would be expected to spontaneously resume estrous cycles within the first couple weeks of the breeding season.

GnRH – PGF +GnRH Systems: This approach is the GnRH – PGF system with the addition of a second GnRH injection (+GnRH) given to all, or some cows, between 48 and 84 hours after PGF (Day 2 to Day 3.5), with timed AI on all or a portion of the herd. These systems are most effective if used on cyclic cows, or anestrous cows that would be expected to spontaneously resume estrous cycles within the first couple weeks of the breeding season. Within this sequence, several variations are available.

GnRH – PGF +GnRH with Timed AI of All Cows
This system involves giving the GnRH treatment on Day –7, PGF on Day 0, +GnRH on Day 2 to 3, and inseminating all cows at the time of the +GnRH injection (Figure 20). No heat detection is performed. A common name for this system is *CO – Synch.* This program was originally developed with +GnRH given on Day 2. Recent evidence suggests that an interval of 2.5 days (60-66 hours after PGF) may increase conception rate, particularly in cows that receive a CIDR treatment from d -7 to 0. A second minor modification to the system is based upon findings that pregnancy rates to this system may be increased by 2 to 8% if cows are inseminated 8 to 16 hours after the +GnRH treatment. This is an approach commonly used in dairy herds, with a common name of *Ovsynch.* This increase in pregnancy rate must be balanced against the labor costs, stress, and inconvenient time interval for moving the cows back through the chute 8 to 16 hours after giving the +GnRH treatment.

GnRH – PGF +GnRH with Timed AI of Cows Not in Estrus Early
This system is identical to the preceding system, with the exception that estrus detection is performed from Days –2 to 1 and cows detected are inseminated 12 hours after detection of heat.

The number of "early" heats averages about 8% of females, with a range of 0 to 15% of treated females across several research studies. The cows inseminated early would not receive the +GnRH treatment and would not be included in the timed AI group. This alteration establishes the need for heat detection for three days, resulting in increased labor costs and animal handling. Conception rate for cows in estrus and inseminated early would be normal, and the conception rate when timed AI is used should increase due to removal of females that were in estrus early.

GnRH – PGF +GnRH with Heat Detection Until Hour 72-84, Timed AI at 72-84 Hours

This approach is actually a hybrid between the *GnRH – PGF* and the *GnRH – PGF +GnRH* systems. Thus, one common name for this system is *Hybrid Synch* and another is *MSU Synch.* This approach is based upon the knowledge that in most herds, a majority of cows that are going to be in estrus will display heat by 60 to 72 hours (Day 2.5 to 3) after PGF. With five days of heat detection (Day –2 to 3), cows that will display estrus are detected and inseminated 12 hours after detection of heat. This time interval "permits" cows that will show estrus in a timely manner to do so and optimizes conception rates for these animals. The remaining animals (not detected in estrus) receive the +GnRH treatment on Day 3 or 3.5 (72-84 hours) and are mass inseminated at this time. Part of this sub-group of the herd consists of cows that would have been in heat after 72-84 hours (Day 3.5 to 6) and cows that are ovulating at an appropriate time but are not displaying a detectable estrus. Conception rates for this portion of the timed AI group should be near that of cows inseminated after detection of standing heat.

The other portion of the cows in the timed AI group would be anestrous cows that did not respond to the earlier treatments and cows in which synchronization of estrus was not achieved. Very few, if any, of these females would be expected to conceive to the timed AI. Therefore, the conception rates for the animals that are timed inseminated can vary widely. If the +GnRH treatment is mainly grouping up animals that would be in heat within the next two to three days, conception rate would be acceptable. If the animals receiving the +GnRH are mainly non-responsive anestrous cows, conception rate in the timed AI group can be very low.

GnRH-Based Systems + Progestins: As indicated in Figure 20, an option is to add a progestin, either a CIDR or MGA, to GnRH-based programs. The vernacular currently being used when a CIDR is used is to add the name of the progestin to the common names identified previously. For example, if a CIDR were added to a Co-Synch program, this would be called a *Co-Synch + CIDR* program. If a CIDR is used as the progestin, it is normally inserted at the time of the initial GnRH injection and withdrawn at the time of the PGF injection. When MGA is used in these programs, it is more common to cite the MGA before the system. For example, when MGA is used in this manner with Select Synch, the common name for this approach is *Short-Term MGA-Select.* Feeding of MGA is normally initiated one day after the initial injection of GnRH (Day –6), and the last feeding of MGA is performed on Day –1.

Inclusion of a progestin in GnRH-based programs guarantees that females will be exposed to a progestin during the period between GnRH and PGF. One reason the progesterone exposure is beneficial is that it ensures that most ovulations occurring in previously anestrous cows, either spontaneously or in response to the +GnRH treatment during the synchrony period, will result in normal (~21 days) rather than short (~10 days) cycles. Furthermore, since the withdrawal of a progestin has been demonstrated to induce onset of cycles in some anestrous females, the likelihood of an ovulation (either spontaneous or

in response to +GnRH) is enhanced. Since the initial response to GnRH can be variable, the inclusion of a progestin removes the requirement that ovulation be induced by GnRH on Day –7. Some data suggests that a CIDR may be more effective in this regard than MGA. A second benefit to inclusion of a progestin in GnRH-based programs is that the early heats (Days –2 to 1) that are inherent to these systems are prevented. The progestin prevents estrus and ovulation between Days –7 and 1. This increased control of the time of ovulation is particularly important in timed AI systems in which no heat detection is performed. The females that show early heats in GnRH-based programs would have conception rates of near 0% if timed AI is performed on Day 2 or 3.

A progestin could be "strategically" used in cattle that are most likely to be anestrus. One approach would be to use progestins in all two-year-old cows and in mature cows that calved less than 45 days before the start of the synchronization program. It has been well established that these types of females are more likely to be anestrus and in need of the additional stimuli that progestins provide. With this approach, the "high-risk" animals are provided with "insurance," and the additional investment in a progestin is not made in the "low-risk" cyclic females. In herds in which a majority of animals are high-risk (e.g., cows in lower body condition), use of a progestin could be expanded to more cows to protect against potential failure.

MGA Pretreatment and GnRH-Based Systems: Derivations of the approach taken in the MGA-PGF system described previously in heifers have been combined with GnRH-based programs for postpartum cows. The MGA – GnRH – PGF program described in Figure 21 is commonly referred to as the *MGA – Select* program. The duration of this program presents challenges relative to the 80- to 85-day interval that exists between the start of calving and the onset of the next breeding season. It is particularly applicable to cattle that calve early in a given season, or to heifers that have been previously bred to calve before onset of the calving season for mature cows. The advantages of progestin use that have been described previously are captured in some animals with this system. Furthermore, since estrous cycles are synchronized with MGA feeding, the effectiveness of the GnRH to reset follicular development should be enhanced.

Figure 21. GnRH-Based Systems With MGA Pretreatment in Cows.
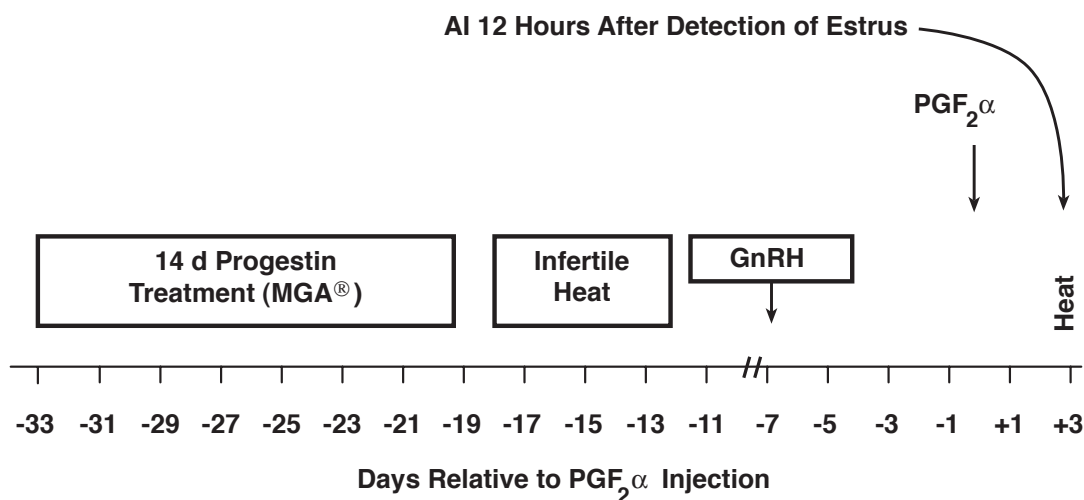
A somewhat similar system, in which the GnRH – PGF treatment is preceded by a seven-day MGA feeding period and PGF is administered on the last day of MGA, is commonly referred to as the *7 – 11 Synch* program. Relative to Figure 21, MGA would be fed on Days –17 to –11; PGF would be administered on Day –11; and the program would then progress as diagrammed. The addition of the injection of PGF and the timing of the MGA feeding shortens the sequence of treatment to 17 days. This duration is more achievable between calving and breeding in many systems.

GnRH-Based Systems + 48 h Weaning: Short-term calf removal is another tool to enhance reproductive performance in AI systems. It has been demonstrated that short-term calf removal will induce ovulation is some anestrous females. However, in the absence of progesterone pre-exposure, the first spontaneous heat after short-term weaning (during the synchrony period), or short-term weaning and an ovulation induced by +GnRH would be expected to be followed by a short estrous cycle (~10 days) that is infertile. For example, if a GnRH – PGF system is followed by calf removal on Days 0 to 2, anestrous cows that did not ovulate to the GnRH (no progesterone pre-exposure) but show heat in response to calf removal are more likely to have a short cycle and low fertility. However, if short-term calf removal is preceded by progesterone from either a GnRH-induced CL or a progestin, such as a CIDR, the ensuing cycle is likely to be of normal length and the potential for establishing a pregnancy exists. Since each of these tools has been shown to stimulate reinitiation of estrous cycles in postpartum cows, together these treatments should provide dual stimuli towards inducing estrus and ovulation. Even when an external progestin is not provided, it has been demonstrated that calf removal tends to increased pregnancy rates when used with a Co-Synch program.

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Summary

Producers may select from a wide variety of synchronization programs for use in *Bos taurus* beef cattle. These systems range from programs that are effective only in cyclic cattle to complex programs that regulate follicular development, provide multiple stimuli designed to induce anestrous females to cycle, and treatments that synchronize ovulation for the purposes of timed AI. There is not a single program that can be identified as "ideal" for all situations. The management capabilities for a given group of females and the mathematical laws of estrous synchronization discussed previously have a major impact upon the system chosen. For example, if maximal conception rate is the primary goal, then systems that use estrous detection and AI are a probable choice. In situations when heat detection is not an option, a timed AI program is the primary option. If the cows to be synchronized calve in a short season, or at a time earlier than planned for the subsequent year, longer-term programs may be a logical choice. Management considerations, such as a desire to minimize the number of times animals are handled or the inability to deliver treatments such as MGA in the feed, are also key determinants of the program chosen. In general, as estrous synchronization requirements are compared for cyclic vs. anestrous females, the complexity of the program necessary to effectively control estrous cycles increases for anestrus. Likewise, in comparison of programs in which AI is performed based upon detection of spontaneous heat vs. timed AI, more complex programs are necessary for timed AI. All programs described have been demonstrated to provide acceptable results when used in the appropriate animal classes.

Producers of pure *Bos indicus* cattle (Brahman) must be aware that small differences exist between their animals and the *Bos taurus* (European and British) or *Bos tauru*s x *Bos indicus* cattle utilized to develop the estrous synchronization systems described in this publication. Timed insemination protocols and protocols to control follicular waves have not been as effective in *Bos indicus* as in *Bos taurus* cattle. Caution should be used in selection of an estrous synchronization protocol that has not been fully tested for *Bos indicus* cattle. Of the programs described, the PGF-based systems have been shown to be equally effective in *Bos indicu*s and *Bos taurus* cattle, although with the two-injection scheme, an interval of 14 or more days between PGF injections has been demonstrated to be most effective. Additionally, *Bos indicus* cattle respond well to the PGF and progestin systems described when cattle are inseminated 12 hours following onset of estrus.

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Citation

This bulletin from Regional Project W-112 included the states and agencies listed below. It is being electronically published with the approval of the Directors of the Western Association of Agricultural Experiment Station Directors. Under the procedure of cooperative publications, it becomes in effect, a separate publication for each of the cooperating stations listed.

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The Ohio State University
Ohio Agricultural Research and Development Center

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Estrous Synchronization (WRP # 014)

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