THE two main problems in beef cattle reproduction are low calf crops and long calving seasons. This paper will not cover all areas of reproduction but will be concerned only with certain aspects of management. Reproductive diseases will not be discussed.

Calf crops as low as 60% and as high as 93% have been reported in experiment station herds (Temple, 1967; Wiltbank et al., 1967). Calf crop in other herds has ranged from 74 to 94% and from 67 to 80% (Wiltbank et al., 1967).

Calving seasons of 6 months or longer are not uncommon in beef cattle operations, and most ranchers calve for at least 90 days. Long breeding and calving seasons perpetuate lowered production in beef cow herds for three reasons: (1) At weaning the calves from late-calving cows are younger and consequently lighter than calves from cows that calve early in the season; (2) Factors such as nutrition, losses at calving and calfhood diseases cannot be controlled adequately; and ranchers hope for success rather than planning effectively for it; and (3) The opportunity for individual cows to have calving intervals of longer than 12 months is greater in long breeding periods than in short breeding periods.

The best opportunities to improve reproductive performance are found in three areas: (1) Increase the number of cows showing estrus during the first 21 days of the breeding season; (2) Increase the conception rate at first service; and (3) Decrease the losses at or near calving. Large variation exists in these three critical areas. The variation in the first two can be demonstrated by data from 11 different ranches in nearly all regions of the United States. The herds were selected for observation because artificial insemination was used, and it was thought that the management in these herds was superior for that area of the country. The cows were also selected. All cows included in the figures had calved at least 60 days prior to the start of the observation period, and most of the cows were nursing calves. The cows were checked for estrus at least twice each day, and all cows were bred by an experienced technician.

The proportion of cows which became pregnant in the first 21 days of the breeding season averaged 39% and varied from 15 to 75% (figure 1). An average of 63% of the cows showed estrus and were bred during the first 21 days of the breeding season, and 61% conceived at first service. The proportion of cows showing estrus the first 21 days of the breeding season varied from 49 to 95%, while the proportion conceiving at first service varied from 33 to 80%. If this selected sample can be considered typical of the reproductive performance in beef cattle herds, then the proportion of cows showing estrus and conceiving early in the breeding season must be increased, and the variation in these two events must be decreased.

Increasing the Proportion of Cows Bred Early in the Breeding Season. There are four variables that largely determine whether a cow will show estrus early in the breeding season: (1) Length of time from calving to start of breeding; (2) The interval from calving to first estrus; (3) Age of the cow; and (4) Level of nutrition before and after calving.

Late-calving cows do not have time to return to estrus early in the breeding season. Two studies point out the effect of reproductive performance in one year on reproductive performance the next year. Reynolds (1967) has shown that cows which became pregnant early in the breeding season one year had a better opportunity to become pregnant the next year. Of 145 young cows which conceived during the first 42 days of the breeding season, 79% became pregnant the following breeding season. By contrast, only 40% of the young cows which became pregnant between the 43rd and 75th day of the first breeding season were pregnant the second year (table 1). The results in the older cows were similar, with 87 and 69% of the cows pregnant the second breeding season for cows bred the first 42 days and the last 33 days of the first breeding season, respectively. Burris and Priode (1958) reported a regression...
of 0.3 of a day for second calving date on first calving date. They also reported that cows calving late tended to have fewer calves than cows calving early. These data indicate that a heifer should conceive early the first breeding season to achieve good reproductive performance throughout her life.

Suckling, age of the cow and nutritional level are important variables affecting the interval from calving to first estrus. Early work in Wisconsin (Clapp, 1937) showed that the interval from calving to first estrus was longer in suckled cows than in milked cows. Later work has substantiated these data (Wiltbank and Cook, 1958; Graves et al., 1968; Reisen et al., 1968) and extended the findings. The interval from calving to first ovulation is longer in suckled cows, and the concentrations of pituitary FSH and prolactin differ between suckled and non-suckled cows. The difference in the average interval from calving to first estrus in suckled and non-suckled cows has varied from 15 to 52 days in the various studies (table 2). These data indicate that the interval from calving to first estrus could be substantially shortened if we would overcome the effect of suckling.

Young cows have a longer interval from calving to first estrus than older cows. In one breeding season the average interval from calving to first estrus was 53.4 days in cows which were 5 years or older, 60.2 days in 4-year-old cows, 66.8 days in 3-year-old cows and 91.6 days in 2-year-old cows (table 3). The causes of the age difference are not known. It could be the result of differences in nutrition. The cows in this study were fed alfalfa hay as a group, possibly producing a marked decrease in energy intake in the younger cows. Whether this is true or not cannot be determined.

By 80 days postpartum, 80% of the cows 5 years or older had shown estrus, while only

TABLE 1. EFFECT OF CONCEPTION TIME ONE YEAR ON PREGNANCY RATE THE FOLLOWING YEAR

<table>
<thead>
<tr>
<th>Conception date first year</th>
<th>Day 1-42</th>
<th>Day 43–75</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young cows</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number cows</td>
<td>145</td>
<td>79</td>
</tr>
<tr>
<td>% pregnant 2nd year</td>
<td>57</td>
<td>40</td>
</tr>
<tr>
<td>Older cows</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number bred</td>
<td>326</td>
<td>78</td>
</tr>
<tr>
<td>% pregnant 2nd year</td>
<td>87</td>
<td>69</td>
</tr>
</tbody>
</table>
68% of the 3-year-old cows had shown estrus (figure 2). Consequently, the interval from calving to first estrus was too long to permit a 12-month calving interval in 32% of the young cows and in 11% of the older cows. We must find methods to shorten this interval from calving to first estrus if we are to have a 12-month calving interval in beef cows.

A low level of energy before or after calving lengthens the interval from calving to first estrus (Wiltbank et al., 1962; Dunn et al., 1969). In one experiment, Hereford and Angus heifers bred to calve at 2 years of age were fed 4.3 lb of TDN (low energy) or 8 lb of TDN (high energy) for 120 days before calving (Dunn et al., 1969). After calving both groups received 13 lb of TDN. The proportions of cows which had shown estrus by 40 days after calving were 7 and 22%, 49 and 81% at 60 days, 73 and 92% at 80 days, and 88 and 97% at 100 days for heifers fed the low and high levels of TDN, respectively (figure 3). If a high proportion of young cows is to show estrus by 60 to 80 days after calving, they must receive adequate levels of energy before calving. Data from older cows are similar (Wiltbank et al., 1962).

Many cows on inadequate levels of energy after calving do not show estrus during the breeding season. Cows which calved at 2 years of age received 8 lb of TDN prior to calving and either 7 lb (low level), 13 lb (medium level), or 22 lb (high level) of TDN after calving. The proportions of cows showing estrus at 40, 60, 80 and 100 days postpartum are shown in figure 4. Only 81% of the heifers receiving the low level of TDN had shown estrus by 100 days after calving, compared to 97% and 98% of the heifers fed the medium and high levels of TDN.

With these facts in mind, we should investigate methods for increasing the number of cows showing estrus early in the breeding season. Some of the research objectives should be: (1) To determine the effect of length of breeding season on the occurrence of estrus early in the breeding season the following year; (2) To compare the economic return from selection of replacement heifers on the basis of early pregnancy only against a system of selection for other criteria; (3) To determine the effect of breeding replacement heifers earlier than the cow herd; (4) To discover ways to shorten the interval from calving to first estrus; and (5) To determine the optimum, as well as the most economical, levels of energy required to cause the onset of estrus following calving.

Short breeding and calving seasons will increase the number of days from the end of calving to the start of the next breeding season. This should increase the proportion of cows showing estrus early in the breeding season. How the pregnancy rate will be affected is unknown but conception rate should be improved. It has been suggested that a 45-day breeding season would decrease calf crop; I doubt that it will. Nutrition has a marked defect on reproductive performance. Therefore, experiments designed to measure the effect of length of breeding season should include cows on various levels of nutrition before and after calving.

Selection of replacement heifers for early pregnancy may appear to be useless in light of the low heritabilities reported for reproductive traits. However, poor reproductive performance perpetuates itself, as evidenced by the reports that a cow calving late with her first calf tends to calve late the rest of her life or to miss calving 1 year. A heifer born to a late-calving cow is likely not to achieve puberty early in the breeding season if bred first as a yearling. What would happen if 50 to 60% more heifers than needed for replacements were bred, and the first heifers to conceive were selected as the replacements?

### Table 2. Interval from Calving to First Estrus in Suckled and Non-Suckled Cows

<table>
<thead>
<tr>
<th>Location</th>
<th>Type of Cow</th>
<th>Suckled (days)</th>
<th>Non-Suckled (days)</th>
<th>Difference (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wisconsin</td>
<td>Holstein</td>
<td>72</td>
<td>46</td>
<td>26</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>Beef</td>
<td>54</td>
<td>18</td>
<td>36</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>Beef</td>
<td>65</td>
<td>30</td>
<td>35</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>Beef</td>
<td>75</td>
<td>30</td>
<td>45</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>Beef</td>
<td>93</td>
<td>41</td>
<td>52</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>Beef</td>
<td>78</td>
<td>34</td>
<td>44</td>
</tr>
<tr>
<td>Maryland</td>
<td>Milking Sh.</td>
<td>104</td>
<td>74</td>
<td>30</td>
</tr>
<tr>
<td>Maryland</td>
<td>Milking Sh.</td>
<td>84</td>
<td>54</td>
<td>30</td>
</tr>
<tr>
<td>Maryland</td>
<td>Holstein</td>
<td>45</td>
<td>30</td>
<td>15</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>Holstein</td>
<td>72</td>
<td>46</td>
<td>26</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>Beef</td>
<td>54</td>
<td>18</td>
<td>36</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>Beef</td>
<td>65</td>
<td>30</td>
<td>35</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>Beef</td>
<td>75</td>
<td>30</td>
<td>45</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>Beef</td>
<td>93</td>
<td>41</td>
<td>52</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>Beef</td>
<td>78</td>
<td>34</td>
<td>44</td>
</tr>
</tbody>
</table>

### Table 3. Interval from Calving to First Estrus in Beef Cows Nursing Calves

<table>
<thead>
<tr>
<th>Age of Cow</th>
<th>No. cows</th>
<th>Avg (days)</th>
<th>No. cows</th>
<th>Avg (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 or older</td>
<td>114</td>
<td>53.4</td>
<td>175</td>
<td>42.6</td>
</tr>
<tr>
<td>4</td>
<td>27</td>
<td>60.2</td>
<td>34</td>
<td>47.7</td>
</tr>
<tr>
<td>3</td>
<td>34</td>
<td>66.8</td>
<td>251</td>
<td>67.9</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>91.6</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
Evidence was cited earlier that young cows nursing their first calves required 15 to 25 days longer to return to estrus following calving. If the breeding season for heifers started 20 days earlier than that of the cow herd and lasted for only 40 days, young cows would have more time to return to estrus following calving. Would breeding an excessive number of heifers earlier than the cows actually improve reproductive performance in young cows? Experiments undertaken to test some of these objectives are in progress; others need to be started.

How can we shorten the postpartum interval to first estrus? To consistently shorten this interval with present technology is difficult, if not impossible. Workers at Nevada (Saiduddin, Quevedo and Foote, 1968; Foote and Hunter, 1964) have shown that postpartum estrus was hastened when estrogen or a combination of progesterone and estrogen was given early in the postpartum period. Injections later in the postpartum period had no effect. Additional studies are needed.

However, in order to approach the problem correctly more information is needed. Hormone levels need to be measured at various stages prepartum and postpartum in groups of cows that differ in the length of the interval from calving to estrus. Differences in the interval from calving to estrus could be produced by feeding high and low levels of nutrition prior to calving or by using suckled and non-suckled cows. The causes of these differences need to be determined. Do the levels of gonadotropic and gonadal hormones differ? Does ovarian sensitivity differ? What are the critical stages for measuring hormone levels? When do hormone levels change? If we could accurately determine why two groups of cows differ in the length of the interval from calving to estrus, we could intelligently approach the problem of diminishing the length of this interval by hormone treatments or management systems.

We can produce differences in the onset of estrus following parturition by varying levels of energy before or after calving. However, the levels of energy which will cause the most economical performance are unknown. Some questions which need to be answered are: (1) What level of energy is the most efficient for causing the onset of estrus? We know levels that will allow estrus to be expressed and levels that won't. What about intermediate levels? (2) Is a constant level of feed best, or can it be fluctuated, and will fluctuation cause more efficient performance? (3) Are the levels of required nutrients the same in all cows? Do breed differences exist? Can crossbred cows perform on lower levels of feed, or is an increased level needed because
of increased size and milk production? Does size of the cow have an effect? Does milking ability affect the amount of nutrients needed for cows to express estrus after calving?

**Conception Rate at First Service.** Conception rate at first service varies greatly in beef cattle herds. The variables affecting conception rate are interrelated and include both the male and female. Thus, poor conception rate could result from low fertility in the female, the male, or both. Many people have speculated on the effect of a single bull on pregnancy rate in multiple-size breeding units. However, little if any data are available. The importance of single bulls on conception rates in beef cow herds is unknown and may or may not be important in overall fertility. A more complete discussion of bull fertility will be left to those who are more competent, and only two variables affecting conception rate at first service in beef cows will be discussed.

Two important variables affecting conception rate at first service in beef cows are: (1) Interval from calving to breeding; and (2) Level of energy following calving.

Numerous experiments in dairy cows and several in beef cows indicate that conception rate at first service increases until approximately 90 days after calving. A summary of this information is presented in table 4 (Casida, Hauser and Tyler, 1968). Some cows in a beef herd will be bred prior to 60 days after calving and consequently will experience low conception rate at first service.

Level of energy after calving affected conception rate at first service in some experiments, while in others little or no effect has been noted (Wiltbank *et al.*, 1962; 1964; Dunn *et al.*, 1969; J. N. Wiltbank, unpublished). Data on older cows (5 to 10 years of age) and 2-year-old cows receiving various levels of energy before and after calving are presented in figure 5. Cows in one group were fed 8 or 9 lb of TDN per head daily for 120 days prior to calving and were in good con-
tion at calving. Cows in the other group were fed 4.5 lb of TDN per head daily for 120 days prior to calving and were thin at calving. After calving one group of cows received 7 or 8 lb of TDN per day and lost weight. Another group were fed 12 to 16 lb of TDN per day and gained 0.5 to 1.0 lb per day. A third group fed 22 to 25 lb of TDN per day gained 1.5 to 2.5 lb per day. The conception rate at first service differed between the groups. The lowest conception rate occurred in cows which were in good condition at calving but were losing weight after calving. Cows which were thin at calving but making rapid weight gains had the highest conception rates at first service in two experiments; however, this was not true in the third.

How can conception rate at first service be improved? First, lengthen the interval from calving to breeding. One way to do this is to shorten the breeding season. The effect of a 45-day breeding season on conception rate needs to be evaluated. Second, determine the cause of the difference between groups of cows that have high conception rate and those with low conception rate. Differences in conception rate between groups of cows needs to be produced. This could be achieved by having one group of cows gaining weight and another losing weight following calving and determining the basis for the difference between the groups. Is it fertilization failure, embryonic loss, or both? If it is fertilization failure, is it caused by defective ova, lack of gamete transport, uterine environment, or other factors? If it is embryonic loss, at what stage does it occur? Hormone levels near the time of loss need to be determined in the two groups. The next step would be to diminish the differences between the two groups by hormones or management systems.

**Losses of Calves at Birth.** Most calf losses occur at or shortly after birth, and the losses range from 5 to 14% (Woodward and Clark, 1959; Bellows, 1966; Temple, 1967; Anderson, 1968). Anderson reported that most losses occur in first-calf heifers. Bellows (1966) indicated that 50% of the calves lost at birth could be saved by improved management.

There is very little factual information available on the processes of gestation and parturition in cattle. Some pertinent questions that need to be answered are: (1) How long does a cow labor, and is this important to calving difficulty? (2) Are presentation, position and posture constant throughout pregnancy? (3) Does the birth canal expand during parturition? If so, what causes that expansion, and can it be altered? (4) Are the size and geometry of the birth canal related.
RESEARCH NEEDS IN BEEF CATTLE REPRODUCTION

100
70
60
50
40
30
20
10
0

Conceived first service

Condition at calving

Good
Thin

2-year-old cows

1st exp. 2nd exp.

Figure 5. Effect of energy level after calving on conception rate.

a Weight change occurring after calving.

to calving difficulty? If so, how and when can they be measured accurately to cull heifers on this basis? (5) What are the effects of calf size and conformation on calving difficulty? We know that heavy birth weight is associated with calving difficulty. Do size and conformation affect presentation, position, posture, or length of labor?

To complete our discussion on reproductive performance of beef cattle, two additional areas, puberty and estrous cycle synchronization, need to be discussed briefly.

Puberty. If a rancher is to calve 2-year-old heifers successfully, the heifers must breed early in the first breeding season. To accomplish this heifers must reach puberty at 13 to 14 months of age and breed successfully at their first or second estrus. Available data indicate that average age at puberty is 413 days for Hereford heifers, 337 days for Angus heifers and 318 days for Shorthorn heifers fed to gain one lb per head per day the first winter (Wiltbank et al., 1966). At 14 months of age there were still 35%, 20% and 19% of Hereford, Angus and Shorthorn heifers, respectively, that had not reached puberty.

We need to know the factors that affect puberty in cattle. Is puberty dependent solely on the production of gonadotropic hormones? Are the gonadotropic hormones produced but not released, or does the ovary fail to respond to available hormones? Again, we need to produce differences in age at puberty and study the cause of these differences. Data indicate that age and weight at puberty are heritable and affected by a genetic-environmental interaction (Wiltbank et al., 1966; Wiltbank, Kasson and Ingalls, 1969). The genetic aspects of puberty need to be explored further with larger numbers.

Other aspects of puberty that need to be explored are: (1) What is the proper feeding level for attaining puberty? Should the level be constant or should it be varied? (2) What size do heifers need to be to attain puberty? Is this related to mature size? Does weight accurately measure this size or are there more accurate measures? (3) Can we select for puberty at an early age without detracting from other economic traits?

Estrous Cycle Synchronization. Estrous cycle synchronization has received a great deal of research attention, yet most of the problems which discourage the widespread application of synchronization in beef cattle remain unsolved.

A large proportion of the treated cows should show heat and conceive during the synchronized estrus. In most synchronization trials, these two conditions have not been met.
Present methods of synchronization are effective only in cows that are cycling. In most herds only 50 to 60% of the cows in the herd are cyclic at the time of treatment (Wiltbank et al., 1967). We must develop a method for inducing estrus in noncyclic animals that will also synchronize cyclic cows or develop a management system that will increase the number of cows that are cycling at time of treatment.

Fertility at the synchronized estrus must be at least equal to that in untreated cattle. Most synchronizing trials in cattle have resulted in relatively poor fertility at the synchronized estrus (Wagner, McAskill and Means, 1963; Wagner et al., 1968; Zimmerman and Clapp, 1937). We need to investigate the causes of low fertility at the synchronized estrus and develop methods for increasing fertility. The hormone levels in the blood during the estrous cycle and following administration of certain hormones should lead to better methods for estrous cycle synchronization. Synchronization of estrus can be an important tool to help improve reproductive performance in beef cow herds, but it should not be thought of as a panacea.

Summary

Three areas present our best opportunity to improve reproductive performance in beef cattle. These are: (1) Increase the proportion of cows bred the first 21 days of the breeding season; (2) Increase the conception rate at first service; and (3) Decrease losses at or near birth. Additional information which can only be obtained from experiments designed solely to obtain physiological data pertaining to beef cattle reproduction is needed.

Literature Cited