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Review: The use of bull breeding soundness evaluation to identify subfertile and infertile bulls

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Efficient and economical herd management depends a great deal on maintaining a short, well-defined calving season. This requires highly fertile females and bulls. Low pregnancy rates are very noticeable, however; potentially greater economic loss may be due to delayed conception. Many studies showed that approximately one of every five bulls had inadequate semen quality, physical soundness, or both, but when evaluation of serving capacity is included about one in four bulls is unsatisfactory. Due mainly to the time and expense that the market will bear, usually only physical soundness and semen quality are evaluated. Breeding soundness evaluation is a useful, low-cost screening method for reducing the risk of using low fertility bulls. The biggest problem with breeding soundness evaluations is not our lack of knowledge or ability, but in the willingness of veterinary schools to provide adequate equipment and training in this area, a lack of diagnostic laboratories equipped to handle the more difficult cases and, most importantly, the weaknesses of human nature that result in negligent testing procedure.

Keywords: bull evaluation, principles, methods, factors, problems

Implications

Efficient and economical herd management depends a great deal on maintaining a short, well-defined, calving season. If short breeding seasons are to be successful, bulls must be selected to be highly fertile. When serving capacity, physical soundness and semen quality are taken into account about one in four bulls is unsatisfactory. Breeding soundness evaluations are a useful, low-cost screening method for reducing the risk of using low fertility bulls. Our knowledge and ability to provide reliable bull breeding soundness evaluation (BBSEs) exceeds what we place into practice due mainly to the time and expense that the market will bear.

Introduction

The objective of this manuscript is to give an overview beef BBSE methods, as observed by the author primarily in North America, but also in several countries of South America, Ireland, the United Kingdom, South Africa and Australia. The main constraint to accurate BBSE is the time and expense incurred by cattle producers and the need for veterinarians to work within those constraints. Veterinary associations must determine best practices in BBSEs that are possible for their area to reduce the risk of using bulls of inadequate fertility. They would need to take into account factors affecting fertility such as seasonal and climatic influences on the management of nutrition and shelter, the main breeds in use, the length of breeding seasons, prevalent reproductive diseases and client acceptance of BBSE procedures.

Definitions of fertility

There are degrees of fertility in cattle populations ranging from individuals with sterility to those able to reproduce at optimum rates. In general we use the terms sterile to mean complete and permanent inability to reproduce, subfertile as depressed reproductive ability, infertile as a temporary inability to reproduce, and fertile as able to reproduce at a normal rate. The term highly fertile also may be used at times and in most bull evaluation systems bulls that are classified as satisfactory potential breeders are expected to be highly fertile, that is, the full potential for fertility in the cow herd can be achieved without any reduction in fertility due to the bull. In highly fertile cow herds, ⩾70% of cows should be pregnant after the first 21 days of the breeding season. Cows that do not become pregnant in the first 21 days would include cows that have not yet begun to cycle after calving, cows in which ovum fertilization failed and cows that had embryonic loss.

The importance of short breeding seasons

In beef herds, efficient and economical herd management depends a great deal on maintaining a short, well-defined,

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calving season. A short calving period results in a uniform calf crop that can be managed as a group for vaccination, castration, weaning, weighing for performance records, and for calf sales. It also allows the cow herd to be managed as a group for maintaining vaccination programs, observation of breeding activity, synchronization of estrus and artificial insemination, pregnancy testing, culling for non-pregnancy and poor performance, and good nutritional management.

In essence, the length of the calving season is dictated by the length of the breeding season. In well-managed herds, it is normal to expect cows to produce a calf every 12 months, and for >90% of the herd to be pregnant and due to calve within a 60 to 80-day period. The use of a short breeding season requires highly fertile cattle. Since the individual bull is usually responsible for pregnancy in 30 to 40 females, his genetic influence on calf quality, as well as on the potential economic risk due to infertility, is far greater than for the individual cow. If short breeding seasons are to be successful, bulls must be selected to be highly fertile. Bulls that pose a potential risk for reduced fertility must be rejected. In beef herds in western Canada it has been determined that the most economical length of breeding season is the length of three estrous cycles, that is, about 65 days resulting in a calving period of 60 to 80 days due to gestational variation (Basarab, 1997). Shorter breeding seasons are feasible with excellent management. At a well-managed ranch in Alberta, Canada, using 1000 cows and heifers, pregnancy rates in cows after a 25-day breeding season have been 85% ± 2% (Barth, 2013).

Economic loss due to subfertile and infertile bulls is commonly measured only in loss due to low pregnancy rates. Low pregnancy rates are very noticeable and can be financially devastating to the individual producer. However, potentially greater economic loss may be due to delayed conception and may not be noticed by the producer. It could be estimated that for every 21-day period of the breeding season that a cow remains open, there is a loss of 23 to 27 kg of weaning weight the following year for the calf she finally conceives. Therefore, low fertility bulls could be the cause of substantial economic losses due to reduced weaning weights a year later. There would be additional losses due to the culling of open cows and cows that conceived late. Cows that calve late tend to do so perpetually in following years.

Prevalence of bulls with reduced fertility

The prevalence of bulls considered unfit for use in breeding programs has been investigated in several studies involving large numbers of bulls (Lagerlof, 1934; Carroll *et al.*, 1963; Elmore *et al.*, 1975). These studies showed that approximately one of every five bulls had inadequate semen quality, physical soundness or both. The prevalence of bulls with low serving capacity was not examined in these studies and, therefore, the proportion of bulls that are unsatisfactory for breeding programs will be considerably higher than indicated by these studies. When serving capacity (a measure of libido and serving ability) is included most likely one of every four bulls is unsatisfactory. The author examined 209 bulls in late April at a federal research station for physical soundness, testis size, semen quality and serving capacity. The bulls were ⩾2 years old and all had a breeding soundness evaluation in a previous year and had been used for breeding. In this group, 72.2% of bulls were satisfactory in all aspects. Management factors, body condition, environmental stresses and photoperiod-related endocrine changes may result in differences in the proportion of bulls with satisfactory breeding soundness classifications at different locations and at different times of the year. In northern regions, for example, Canada, United Kingdom, Ireland, Scandinavia, short photoperiod has a strong effect on bull semen quality such that evaluations conducted in late winter to early spring will result in a significantly lower percentage of bulls with good semen quality than when evaluations are conducted in late spring or summer (Barth and Waldner, 2002).

Methods of bull breeding soundness evaluation

There is some variability in how bulls are evaluated for breeding soundness in different parts of the world, however, three cardinal principles of breeding soundness are acknowledged in all systems. They are that bulls must be physically sound (includes scrotal circumference (SC)), have good sex drive and be able to deliver semen of good quality to the females they serve. Freedom from sexually transmissible diseases, which is often not included in BBSEs, could be included as a 4th cardinal principle. In areas where campylobacteriosis and trichomoniasis are prevalent, testing for these diseases may be done at least partially in conjunction with BBSEs.

Our knowledge and ability to provide reliable BBSEs exceeds what we place into practice. Unfortunately, due mainly to the time and expense that the market will bear, usually only physical soundness and semen quality are evaluated. Some BBSE forms cover the 3rd cardinal principle of serving capacity by emphasizing that cattle producers must observe mating to be sure that bulls are actually breeding cows. Veterinarians may also verbally advise producers to watch for serving problems, as well as cow returns to estrus, daily or at least several times a week during the breeding season. The end result is a useful low-cost screening method for reducing the risk of using low fertility bulls. We are more likely to err on giving a satisfactory classification to unsatisfactory bulls than we are to err in failing to cull low fertility bulls.

There is no doubt that at least a small percentage of bulls that are classified as satisfactory, by even the most conscientious examiners, will fail in one or more of the cardinal principles of breeding soundness. Very few include serving capacity tests in routine BBSEs. However, in a definitive study in which physically sound, low, medium and high libido bulls were placed with normal cyclic females in separate pastures, low libido bulls left fewer calves and resulted in delays in calving in cows that had conceived. Therefore, libido alone is an important aspect of breeding soundness and it has been shown that 10%, or more of bulls have low libido (Blockey, 1980; Coulter and Kozub, 1989).

Physical soundness exams are actually physical inspections that miss less-easily-visible problems. For example, in one study (Barth *et al*., 2004) breeding soundness examinations were done twice on 165 bulls, once by a conventional protocol using electroejaculation, followed on the same day, or 1 week later, using mount cows fitted with an internal artificial vagina (IAV). Semen collection by IAV allowed libido assessment and the detection of physical problems that prevented mating. In that study, inability to serve due to collapse of the hocks upon mounting, penile corkscrewing or misdirection of the penis, was found in eight bulls (4.8%) that otherwise demonstrated good libido and had been determined to be satisfactory potential breeders by physical inspection and semen collection by electroejaculation.

Often 2 to 3 months pass between breeding soundness examinations and the beginning of breeding seasons particularly for bulls purchased at sales. Veterinarians need to be aware of the effect of bull factors and environmental factors that might affect breeding soundness outcomes between testing and the onset of breeding.

Factors affecting bull breeding soundness evaluation outcomes

Bull factors

Age. Age at puberty, and subsequently maturity, is the main factor involved in semen quality in yearling bulls. In North America, most bulls offered for sale are 12 to 15 months old. Unfortunately, a large proportion of bulls are sexually immature at this time. Nevertheless, BBSEs are done before sales and, not uncommonly, many immature bulls are misleadingly classified as satisfactory potential breeders. This appears to be based on speculation by veterinary examiners that within a few weeks, or months the majority of immature bulls will be able to produce good semen just in time for the breeding season. However, the purchasers of such speculative bulls often had unexpected poor results when bulls were placed into breeding programs. In general, we would expect 10% to 15% of physically normal mature bulls to have unsatisfactory semen quality in prebreeding-season semen tests. Thus if the reason for a decision deferred classification in physically normal pubertal bulls is inadequate semen quality, one might expect 85% of them to have satisfactory semen quality at the age of maturity, which may be considered to be 16 months of age for Bos taurus bulls. However, data from a recent study indicated otherwise (Barth, 2013). In that study, 524 yearling bulls were tested at 13 to 15 months of age over 4 years (2008–11) during 15 to 21 April. Unsatisfactory bulls were culled for such things as small testes, epididymitis and locomotory abnormalities. Physically sound bulls that were classified as decision deferred due to inadequate semen quality ($n = 85$) were retested at 15 to 17 months of age (11 to 15 June). Only 25 of the 85 bulls (35.2%) had good semen quality at the second test. Therefore, it is very unwise for veterinarians to speculate that most pubertal bulls will have good semen quality after an additional month or two for maturation.

In mature bulls, when the effects of physical abnormalities, including slight frostbite, body condition scores (BCSs) below 2.5 or above 3.5, and below the minimum recommended SC measurement were excluded, $\geq$80.0% of bulls in all age groups 6 year old, or less had satisfactory semen quality and there was no difference between age groups in the proportion of bulls that had satisfactory semen quality. However, the odds of 2-year-old bulls having a satisfactory BBSE classification were lower than for 1-, 3- and 4-year-old bulls due to an increased likelihood of physical abnormalities and poor, or excessive body condition. It is likely that bulls greater than 2 years of age would already have been culled for physical abnormalities that lead to semen quality or mating ability issues (Barth and Waldner, 2002).

Body condition. It is well known that excessive body fat in bulls is detrimental to fertility in bulls, but still it is one of the most common problems encountered with bulls offered for sale in much of the world. Poor body condition due to low quality pastures, or inadequate nutrition and shelter in northern climates, also reduces the percentage of bulls with satisfactory semen quality. In a study in western Canada, involving 2110 Bos taurus beef bulls, when only physically normal bulls were considered, but including all BCSs, significantly fewer bulls with a BCS of 2.0/5.0 had satisfactory semen quality compared with bulls with a BCS of 3.0 or 3.5/5.0 (Barth and Waldner, 2002). Low body condition in mid- and late-winter would likely indicate inadequate nutrition for regaining weight lost during the breeding season. Although the adverse effects of undernourishment cannot be discounted, the effect of cold stress might be more severe in bulls without adequate body fat.

Physical abnormalities. The percentage of bulls with satisfactory semen quality in the presence of abnormalities of the feet and legs, the scrotum and the testes were 59.5%, 34.7% and 7.7%, respectively (Barth and Waldner, 2002). However, depending on type and severity, physical abnormalities did not necessarily preclude a satisfactory classification of potential breeding soundness. Feet and leg abnormalities such as the corkscrew claw defect, or post-like hind legs that did not result in lameness were not significantly associated with semen quality. However, lameness was a very important factor affecting semen quality as only 4 of 17 lame bulls had a satisfactory rating. This is expected since pain in the feet and legs would adversely affect the endocrine secretion of LH reducing testosterone production important in the maintenance of normal spermatogenesis (Welsh and Johnson, 1981; Barth, 1994). Foot and leg abnormalities without lameness are a serious issue in BBSEs as these predispose bulls to developing lameness at a later date.

Scrotal circumference. A great deal of emphasis is placed on the selection of bulls with large SC measurements as a means for selecting for early puberty (Barth, 2013). In addition, a

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significantly higher number of mature bulls with above average, or average SC, had satisfactory semen quality than bulls with below average, or below the recommended minimum SC (Barth and Waldner, 2002). Bulls with below the recommended minimum SC had lower numbers of morphologically normal sperm and sperm staining alive than bulls with average, or above average SC measurements. Bulls with below minimum SC and below average SC had lower percentages of progressively motile sperm than bulls with average, or above average SC. This provides some assurance that the current recommended practices of bull selection based on SC are also valid for increasing the likelihood that a bull will produce good quality semen. Others also have reported significant positive correlations of SC with good semen quality (Gibson *et al.*, 1985; Rao Veeramachaneni *et al.*, 1986).

Environmental factors

Season. Studies of bulls in western Canada have shown that bull fertility is affected by photoperiod. The percentage of bulls with satisfactory semen quality increased as time progressed from the colder months of January and February toward the warmer months of May and June. This resulted in increasing percentages of bulls with satisfactory BBSE classifications as time progressed toward the warmer months. The improvement in semen quality occurred in all bulls including physically normal bulls in normal body condition. This suggests that a combination of a short photoperiod, cold stress and reduced feed quality may be detrimental to spermatogenesis. Feed quality is less likely to be a factor affecting semen quality than either of the former since significantly more bulls had satisfactory semen quality in March and April than in January and February despite being on the same supply of stored feed (Barth and Waldner, 2002).

In three groups of mature bulls, five bulls per group over 3 years, serial blood sampling over a 10-h period at the solstices and equinoxes showed that testosterone concentrations were lowest in fall and winter, improving during the spring and peaking in June (Barth, 2013). The bulls were confined in a large pen with good shelter and bedding and provided with good quality hay. During very cold periods they were supplemented with oat grain. The bulls maintained good body condition and SC did not change significantly with season.

Adequate levels of blood and testis tissue testosterone are known to be important for normal spermatogenesis (Courot *et al.*, 1979; Zirkin *et al.*, 1989). Therefore, photoperiod may have an effect on semen quality since seasonal variation in LH and testosterone has been reported in bulls (Phillipps *et al.*, 1943; Sundby and Tollman, 1978; Welsh *et al.*, 1981).

Nutrition. Nearly all research in bull development has been concentrated in the post-weaning period. This has overlooked a very important period of development in a bull's life – calfhood. There are indications of a strong effect of calfhood nutrition on age at puberty and testis size implying superior nutrition leads earlier maturity and larger lifetime testis size (Barth *et al.*, 2008).

Bulls that are managed for sale as yearlings usually are fed high-energy diets in the post-weaning period to maximize rates of gain in BW. High-energy diets with adequate protein, vitamins and minerals are likely to result in a larger SC at a year of age, however, at least part of this increase in size is likely due to scrotal fat (Seidel *et al.*, 1980). There are conflicting reports about whether testis size and age at maturity are significantly affected by nutritional intake in the post-weaning period (Pruitt *et al.*, 1986; Coulter *et al.*, 1987; Mwansa and Makarechian, 1991; Ohl *et al.*, 1996). The larger testis size seen in some studies when calves received superior post-weaning nutrition was likely due to greater numbers of germinal cells supported by each Sertoli cell rather than larger numbers of Sertoli cells, or greater potential size of seminiferous tubules (Barth *et al.*, 2008). It was shown that inhibition of the rise in gonadotrophin secretion before 20 weeks of age in bull calves resulted in fewer germinal cells per seminiferous tubule cross section than in bulls with normal or augmented gonadotrophin secretion at that age (Chandolia *et al.*, 1997). This implies that Sertoli cells can run at 'half empty' under less than ideal conditions and this could in turn result in less turgid and smaller testes. Therefore, bulls with slower weight gains in the post-weaning period might have no reduction in Sertoli cells, but have fewer germinal cells per Sertoli cell and thus smaller testes at a year of age. However, with the normal compliment of Sertoli cells in place, due to good early calfhood nutrition, there would be no reduction in potential adult testis size, or semen production capability.

Many breeders of pure bred bulls claim that to obtain maximum prices bulls must be 'well fitted' for sales, that is, fattened. It has been shown that bulls fed to 2 years of age on high-energy diets had reduced sperm output, reduced sperm motility and increased proportions of sperm abnormalities (Coulter and Kozub, 1984). Furthermore, even when the high plane of nutrition was reduced after 2 years of age, the trend towards production of abnormal spermatozoa continued. The lowered semen quality probably was due to scrotal fat deposition causing abnormal testis thermoregulation (Coulter *et al.*, 1997).

In the western range land of North America, breeding seasons usually occur in late spring and early summer taking advantage of favorable pasture conditions for milk production and fertility in beef herds. Bulls tend to lose a considerable amount of weight in the breeding season and may continue to lose weight particularly on native pastures that enter dormancy in late summer and early autumn. Bulls that lose weight can be expected to lose up to 2 cm of SC between early spring and autumn (Barth, 2012). The decline in SC is often accompanied by a decline in semen quality. Somewhat similarly, in other areas of the world, seasonal drought conditions resulting in poor pasture and loss of weight can result in loss of testis size and impact semen quality. For example, the adverse effects of poor pasture on testis function and the need for protein supplementation was

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reported for crossbred Brahman bulls in western Australia. Protein supplementation resulted in maintenance of SC, whereas, SC decreased in non-supplemented bulls. Weights of testes, epididymides and vesicular glands were greater in supplemented bulls (Ndama *et al*., 1983). Basically, these physiological changes are driven by changes in metabolic hormones that signal to the hypothalamus about adverse environmental conditions. In response, a reduction in the production of gonadotrophic hormones results in reduced germ cell proliferation in the testes. Reduced numbers of germinal cells per Sertoli cell would result in a decline in testis mass. Nutritional signals exert powerful effects on the reproductive system of mature male ruminants. Peripheral metabolic hormones including leptin, insulin, growth hormone and IGF, signal nutritional status to the gonadotrophin releasing hormone neurons in the hypothalamus which are the primary regulators of fertility (Abele *et al*., 1986; Martin and Walkden-Brown, 1995). These metabolic hormones may also have direct effects on the testes. Receptors for these hormones have been detected in various cell types in the testes (Bellve and Zheng, 1989; Lin, 1995; El-Hefnawy *et al*., 2000). These hormones affected Leydig cell steroidogenesis *in vitro* and may be involved in testicular cell multiplication and differentiation (Caprio *et al*., 2003; Wang *et al*., 2003).

People factors

Differences between SC measurements between veterinarians has long been a source of contention, particularly for sale bulls that do not meet the requirements by a close margin. Incorrect measurement technique, the amount of SC tape tension applied by different people and temperature effects on scrotal wall thickness are the main sources of error. Spring tension SC tapes help to reduce error, but careful testis palpation and SC measurement cannot be over emphasized.

Semen is evaluated by light microscopy in the field, at veterinary facilities, and in Australia, by trained personnel in semen evaluation centers. The author has been involved in at least 20 workshops on semen evaluation in seven countries over a period of about 35 years where microscopes were provided by practitioners themselves, or by veterinary schools. Most veterinarians have a great deal of confidence in their ability to adequately examine semen by microscopy, however, there was a great deal of variation in both the quality of microscopes used by veterinarians and in the ability of veterinarians to do basic microscope maintenance and microscopic assessment of semen. Furthermore, the author has encountered evidence on many occasions that veterinarians, perhaps for reasons of expediency, try to assess semen quality from samples and, or semen smears which they know to be inadequate. One or two even failed to use a microscope at all. Institutions are not blameless. Microscopes with inadequate optics for semen evaluation are commonly used in schools and microscope maintenance and adjustment are not given any teaching emphasis. Inadequate understanding by school faculty of microscopic evaluation of semen is witnessed by the perpetration upon the veterinary populace of a BBSE system which maintains that 30% sperm motility is adequate for a satisfactory classification of bulls. The difficulty in obtaining adequate semen samples is increased in yearling, pubertal bulls intended for sales. There are veterinarians that are willing to test very large numbers of yearling sale bulls in very short periods of time with unduly high pass rates of bulls in order to procure lucrative contracts.

The biggest problem with BBSEs is not our lack of knowledge or ability. Rather, the problem lies in the willingness of veterinary schools to provide adequate equipment and training, a lack of diagnostic laboratories equipped to handle at least the more difficult cases and, most importantly, the difficulties of human nature that result in negligent testing procedure. What can be done to ensure that BBSEs are done more thoroughly? Upgrading the education of practitioners has been the subject of many conferences and workshops and, although this is laudable and effective, not all veterinarians avail themselves of these opportunities. Clearly, a great many veterinary schools all over the world need to upgrade this part of their programs. Australia has taken the lead in providing a semen evaluation service in centralized well-equipped laboratories with trained personnel. This should, or would solve a large part of the problem with variability in the quality of semen evaluation by veterinary practitioners. However, the Australian concept may be difficult to sell in other parts of the world. Each country's veterinary associations must work toward solutions that are appropriate for their own situation. If the subject of maintaining a high level of competence in BBSE stays in view, progress can be made.

In some areas, veterinary associations require that all practices must retain a copy of BBSEs as well as labeled semen smears for a period of 1 or more years. Practice inspections and complaints have lead to reviews of evaluation forms and semen smears resulting in fines and retraining requirements for some veterinarians in Canada. The Western Canadian Association of Bovine Practitioners conducted a survey to consider the problem of inadequacy of yearling sale bull evaluations. A survey was sent out to 141 veterinary practices and 51 responded. The following sample of commentary from the survey shows that veterinarians are very aware of problems in the industry, but do not readily agree on solutions:

- Producers take failing bulls to different clinics until they find someone who will pass them
- We should do anything we can to stop veterinarians going easy on bulls making BBSE's a farce
- There will always be those that try to beat the system
- If we promote testing only after sale, many bulls will not be tested as the deal is done
- BBSE forms should state that examinations under a certain age are inaccurate
- The only way to change anything is with legislation
- We are not in favor of legislation

One outcome of the survey was a change on the BBSE form to educate producers on what percentage of yearling

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sale bulls actually could be expected to have a satisfactory classification. The change was to add a line on the BBSE form after the Decision Deferred category that states: 'About 45%, 60% and 75% are expected to pass at 12, 13 and 14 months of age, respectively. Testing at under 12 months of age is not recommended'. The percentage figures in the above recommendation are based on data from the main British and Continental breeds of bulls in use across Canada. The figures were produced by consensus of opinion and were intended as an educational tool for producers that previously might have believed all bulls would be mature at the time of testing. The statement might also discourage veterinarians from falsely providing very high percentages of satisfactory breeding soundness classifications on speculation that the poor semen quality of immature bulls would soon become satisfactory. The back of the BBSE form provides a great deal of information for all to see on mean SC by age and breed. Most likely different regions of the world would need to conduct studies to determine whether these figures are suitable for their bull populations.

The present methods of BBSE are very useful screening tools for reducing the risk of placing lowly fertile bulls in the breeding herd. We must recognize that, with the limitations of time and money that producers would be willing to invest in the procedure, we will always give satisfactory classifications to some bulls that are actually unsatisfactory. Veterinary organizations in various regions of the world must be vigilant to ensure adequate training of veterinarians involved in BBSE. Well equipped multispecies diagnostic laboratories specializing in semen evaluation are needed everywhere. Such laboratories might have improved prospects for viability if staffed and equipped to handle other advanced reproductive procedures and funded for diagnostic work and research.

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Ethics statement

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