ELSEVIER

Theriogenology 57 (2002) 2015–2025

Theriogenology

Impact of boar exposure on puberty attainment and breeding outcomes in gilts

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Received 8 January 2001; accepted 18 July 2001

Abstract

We examined the most effective method of boar exposure for the attainment of puberty in 89 gilts. At 160 days of age, we allocated gilts to daily direct contact with a vasectomized boar after movement of pen groups of gilts to a detection–mating area (DGB: $n = 30$); daily direct contact with boars in the gilt home pens (DBG: $n = 31$); or daily fenceline contact between boars and gilts housed in individual gilt stalls (FBG: $n = 28$). DGB gilts were younger ($P \leq 0.05$) than FBG gilts at puberty. Direct boar contact reduced the interval from initial boar contact to puberty in DGB and DBG gilts, compared to fenceline contact in FBG gilts ($P < 0.05$). There was no difference ($P \geq 0.05$) between treatment for pubertal weight, backfat, lifetime growth rate, or duration of first pubertal estrus. Backfat depth and leptin concentration at 160 days of age were positively correlated ($P \leq 0.05$). We detected no relationships between leptin or IGF-1 concentration at 160 days of age and the interval from initial exposure to a vasectomized boar to puberty ($P > 0.05$). Based on objective criteria, fenceline contact with a boar (BC) during artificial insemination improved the quality of artificial insemination compared to no boar contact (NC) ($P < 0.05$).

Keywords: Gilt; Puberty; Boar; Leptin

1. Introduction

It is well established that the exposure of prepubertal gilts to a mature boar is an effective means of inducing puberty [1,2]. This effect is largely due to the synergistic action of the boar stimuli components: visual, tactile, olfactory, and auditory cues [3]. There are several

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0093-691X/02/$ – see front matter
PII: S0093-691X(02)00674-X

methods by which a mature boar can be used to stimulate puberty: fenceline stimulation, gilts moved to the boar pen, gilts and boar moved to a common pen, boars moved to the gilt pen, and continuous housing of gilts and boars together [1,2].

In large modern production units, there is pressure to maintain a continuous flow of cyclic gilts to meet breeding targets. Housing, time, and labor constraints often determine which method of boar exposure is utilized. However, it is important for a producer to adopt a method of puberty stimulation that most effectively induces early puberty in gilts. It has been shown that physical contact between a boar and a group of gilts is a more effective stimulus than fenceline contact for triggering an earlier first estrus in gilts [1,4]. Moreover, van Lunen and Aherne [2] reported that a larger proportion of gilts reached puberty by 270 days when gilts were taken to the boar, compared to when a boar was taken to the gilt pen for puberty stimulation. Because of the importance of good boar exposure techniques for effective gilt pool management, it seems appropriate to re-evaluate existing literature and to compare stimulation using direct contact with boars with less direct stimulation of stall-housed gilts.

Researchers have long sought for a key metabolic signal for puberty onset in mammals [5]. The newly discovered ob gene, which codes for leptin, has been reported to be involved in the onset of puberty in mice [6]. Although leptin may be an important link signaling metabolic status to the reproductive system, it has already been determined that other metabolic cues, like insulin-like growth factor (IGF-1), may be involved in the timing of puberty [7]. However, literature showing the relationships between leptin, IGF-1 and puberty in farm animals is limited.

The presence of a boar has been shown to exert physiological effects on the female at breeding. Circulating oxytocin levels in the sow increase when sows are subjected to olfactory [8] and tactile stimulation [9], which stimulate uterine and oviductal contractions [9]. Oxytocin also acts as a stimulus for PGF2α secretion [10].

The first goal of this study was to examine three different methods of boar exposure to determine which method is the most effective for stimulating gilts to reach puberty in a modern commercial genotype. A second goal of this study was to determine relationships between plasma IGF-1 and leptin concentrations and reproductive parameters. The third objective for this study was to determine if the lack of a boar at breeding has negative consequences for the quality of the insemination and subsequent litter size.

2. Materials and methods

2.1. Part 1

We completed this study at the University of Alberta Swine Research Unit with approval from the Faculty Animal Policy and Welfare Committee. We used 89 prepubertal Large White grandparental gilts (Genex Swine Group, Regina, Sask., Canada) in this experiment. At approximately 160 days of age, groups of gilts were stratified according to growth rate and randomly allocated to one of three puberty stimulation treatments: direct contact of group pens of gilts with a vasectomized boar in a boar stimulation pen (DGB: $n = 30$); direct contact with a vasectomized boar in gilt home pens (DBG: $n = 31$); or fenceline

contact between a vasectomized boar and gilts housed in individual gilt stalls (FBG: $n = 28$). Gilts in pens were housed in groups of six. All gilts were housed on fully slatted floors, with natural daylight from overhead skylights. We calculated pen floor space allowance as recommended for growing pigs on fully slatted floors (Agriculture and Agri-Food Canada, 1993); we permitted each gilt at least 1.2 m^2 space allowance throughout the entire trial.

We fed all gilts a grower diet to appetite, formulated to provide 16% crude protein, 3.2 Mcal/kg of digestible energy and 0.75% lysine, and provided ad libitum access to water throughout the trial. We measured feed disappearances weekly for group-housed gilts and daily for stall-housed gilts.

Gilts were exposed to boars twice daily for detection of onset and duration of their pubertal estrus. For all groups, we defined puberty attainment as the time that gilts first exhibited a standing reflex in response to the back pressure test (BPT) during twice daily (07:00 and 19:00 h) fenceline contact with a boar. Gilts were then provided their allotted method of boar stimulation for 10–15 min. One of four mature vasectomized boars were used for stimulation and gilts were not exposed to the same boar twice in 1 day. Age, weight, and backfat depth (measured at the last rib, 6 mm off the midline) at puberty, and duration of pubertal estrus, were recorded. At the onset of their pubertal estrus, we relocated group-housed gilts to individual stalls and then allocated them to a breeding group. To synchronize estrus we gave them 15.4 mg of Regumate daily as an oil-based top dressing from Day 15 of the cycle.

As they entered the gilt facility, we took a 5 ml jugular blood sample from all gilts. Every 10 days thereafter, until Day 160 (commencement of boar stimulation), and every 10 days from Day 190 until Day 210, we took a 5 ml jugular blood sample to ensure that gilts had not ovulated. All blood samples were taken during a brief period of nose–snare restraint and centrifuged at 3000 rpm for 15 min; we then decanted plasma and stored it at $-20\ ^{\circ}C$ until analysis for plasma progesterone concentration. We also analyzed the Day 160 samples for leptin and IGF-1.

For all radioimmunoassays (RIA), we analyzed all samples in duplicate. Assay sensitivity was calculated using the following equation: where B_{max} was the average of the zero standard tubes for that assay $[(B_{max}) - 2\text{S.D.}(B_{max})/\text{average}(B_{max})] \times 100$. We determined plasma progesterone concentrations using a kit RIA (Coat-a-Count Progesterone, Diagnostic Products Corporation, Los Angeles, CA, USA), previously validated for use with porcine plasma without extraction [11]. The sensitivity of the assay was 0.1 ng/ml, the intra-assay coefficients of variance (CV) was 5.4% and the inter-assay CV was 7.7%. We determined plasma IGF-1 concentrations using the homologous double antibody RIA described by Cosgrove et al. [12]. We initially extracted 100 μl of plasma with 3 ml of acid ethanol. Radio inert recovery efficiency for the single assay run was 109%, the intra-assay CV was 8.9%, and sensitivity of the assay, estimated as 87% bound, was 0.012 ng/tube. Plasma leptin concentrations were determined using the multi-species double antibody kit assay, previously validated by Mao et al. [13] for use in our laboratory. All leptin values reported as nanogram equivalents of human leptin/ml plasma. The sensitivity of the single assay was 0.2 ng/ml and the intra-assay CV was 15.5%.

For statistical analysis, all gilts with a progesterone concentration above 1 ng/ml before boar contact at 160 days of age were considered pubertal and removed from the analysis.

We also removed gilts from the analysis if they reached puberty within 3 days of the commencement of boar stimulation. We removed any lame gilts from trial.

2.2. Part 2

After gilts completed the trial in Part 1, we assigned a portion of the gilts to one of two treatments based on weight at pubertal estrus: fenceline contact with a boar during artificial insemination (BC, $n = 20$), or no contact with a boar for a minimum of 60 min prior to, or during, artificial insemination (NC, $n = 14$). We checked gilts twice daily following the removal of Regumate for onset of standing heat, at which time we recorded gilt weight, P2, and heat number. Gilts were bred in their stall 12 and 24 h after the onset of standing heat by artificial insemination using 3×10^9 pooled sperm in 70 ml extender, derived from designated, fertile Genex boars. Semen was not older than 3 days from the collection date. We checked all NC gilts for standing heat. Once all NC were heat checked, we heat checked and bred all BC gilts. One hour after any contact with boars, we bred NC gilts. To determine the gilt's first response to the boar, we initially treated all gilts equally, using minimal stimulation by the animal technician. Depending on the gilts' initial response to the boar, the technician then used varying amounts of stimulation to elicit a standing response in the gilt. We scored breedings using the following criteria: (1) Excellent Breeding, gilt showed a standing reflex as soon as BPT was applied and gilt stood well for the entire breeding; (2) Very Good Breeding, gilt did not show a standing reflex as soon as BPT was applied and needed more stimulation than category (1) but stood well for the entire breeding; (3) Good Breeding, gilt exhibited a standing reflex as soon as BPT was applied but did not stand well to BPT through the entire breeding; (4) Satisfactory Breeding, gilt did not show a standing reflex as soon as BPT was applied and did not stand through the entire breeding period; (5) Bad Breeding, gilt did not show a standing reflex as soon as BPT was applied, needed more stimulation from technician than category (4) to finally elicit a standing reflex, and did not exhibit the standing reflex throughout the entire breeding.

3. Statistical analysis

3.1. Part 1

We analyzed differences between DBG, DGB, and FBG gilts for age at puberty, days to puberty from initial boar exposure, weight, backfat, duration of pubertal estrus, leptin and IGF-1 concentrations, and total and average feed intakes using the SAS GLM procedure [14]. For all these variables, we included only treatment in the model, because all other variables were not significant. We used age, weight, and backfat depth at 160 days as covariates for age, weight, and backfat at puberty, respectively. If we determined treatment differences, we performed multiple comparisons between means, adjusted by the Student–Newman–Keuls test [14]. All data are represented by mean $\pm$ S.E. We analyzed differences in the number of gilts not pubertal at the completion of the trial using chi-square analysis [14]. We used correlation analysis [14] to determine the associations among IGF-1, leptin, backfat depth, and age at puberty.

3.2. Part 2

We analyzed differences between NC and BC gilts for breed Scores 1 and 2, and subsequent litter size using the SAS GLM procedure [14]. We included treatment and the cycle at which a gilt was bred in the model. If we detected treatment differences, we performed multiple comparisons between means, adjusted by the Student–Newman–Keuls test [14].

4. Results

4.1. Part 1

Of the 89 gilts that were allocated to treatment, we removed a total of 21 animals from the analysis: six exhibited silent ovulations, nine reached their pubertal estrus within 3 days of the initiation of boar exposure and six gilts were lame. Of the remaining 68 gilts, there were no differences ($P > 0.05$) between DGB, DBG, and FBG gilts in age (159.2 ± 0.6, 159.8 ± 0.8 and 159.1 ± 0.8 days), weight (103.5 ± 1.7, 109.0 ± 1.4 and 108.2 ± 2.8 kg) or backfat depth (12.3 ± 0.5, 13.1 ± 0.4 and 13.5 ± 0.9 mm), respectively, at the start of treatment.

Table 1 shows the various parameters measured at the first pubertal estrus for gilts. DGB gilts were younger ($P < 0.05$) than FBG gilts, with DBG gilts being intermediate for age at puberty. Direct boar contact reduced the interval from initial boar contact to puberty in DGB and DBG gilts compared with FBG gilts ($P < 0.05$). There were no differences ($P > 0.05$) between treatment for pubertal weight, backfat thickness, lifetime growth rate, or duration of pubertal estrus. Treatment affected total and average feed disappearances ($P \leq 0.05$).

The effect of method of boar exposure on the dynamics of puberty attainment is shown in Fig. 1. DGB and DBG gilts showed a similar pattern of puberty onset; however, reflecting the increase in number of days to first estrus (Table 1), FBG gilts showed a delay of 12 days before any gilts reached their pubertal estrus. The proportion of gilts to reach puberty by 215 days was not different between treatments, DGB (96%), DBG (82%), and FBG (81%).

There were no differences ($P > 0.05$) between DGB, DBG, and FBG gilts in leptin (3.7 ± 1.7, 3.4 ± 1.4 and 3.4 ± 2.2 ng/ml) or IGF-1 concentrations (129.3 ± 20.2, 128.9 ± 29.5 and 132.6 ± 25.5 ng/ml), respectively, at the start of treatment. Backfat depth and leptin concentration at 160 days of age were positively correlated (Fig. 2) ($P \leq 0.05$). We detected no relationships between leptin or IGF-1 concentration at 160 days of age and the interval from initial exposure to a vasectomized boar to puberty ($P > 0.05$).

4.2. Part 2

At breeding, there were no differences ($P > 0.05$) between BC and NC treatments in age (244.4 ± 2.8 and 241.3 ± 5.3 days), body weight (155.6 ± 3.5 and 152.0 ± 3.6 kg),

Table 1
Mean (±S.E.M.) age, weight, backfat depth, growth rate, estrus length, and feed intakes for gilts receiving direct contact with a vasectomized boar in a purpose built boar stimulation area (DGB), direct contact with boars in gilt group pens (DBG), and fenceline contact between boars and gilts housed in individual gilt stalls (FBG)[a]

	Pubertal estrus						Feed intake[b]	
	Age (days)	Days to estrus[c]	Weight (kg)	Backfat (mm)	Growth rate (kg/day)[d]	Estrus duration (h)	Total (kg)	Average (kg/day)
DGB ($n = 25$)	180.9 (2.5) e	21.8 (2.7) e	124.3 (3.6)	15.8 (1.0)	0.68 (0.01)	37.6 (3.4)	65.0 (7.0) e	3.0 (0.07) e
DBG ($n = 22$)	183.8 (3.5) ef	24.0 (4.0) e	129.8 (4.7)	15.7 (0.8)	0.71 (0.02)	40.5 (3.2)	80.1 (13.4) f	3.1 (0.06) ef
FBG ($n = 21$)	191.1 (2.8) f	32.0 (3.2) f	139.2 (4.5)	17.3 (1.0)	0.73 (0.02)	45.4 (4.5)	110.4 (12.7) g	3.3 (0.1) f
P	0.039	0.039	0.12	0.45	0.35	0.24	0.017	0.03

[a] Means in a column with different letters are different ($P < 0.05$).
[b] Total and average feeds consumed over the entire period from initial boar exposure until puberty.
[c] Interval from initial exposure to a vasectomized boar until puberty.
[d] Lifetime growth rate (birth to onset of puberty).

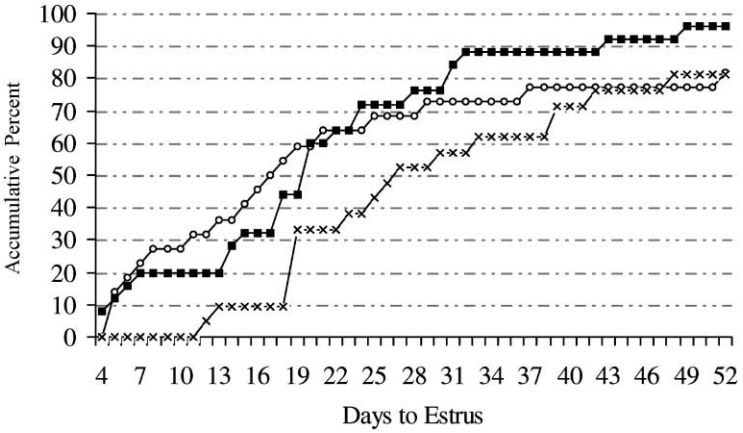

Fig. 1. Accumulative percentage of gilts attaining puberty in response to direct contact with a vasectomized boar in a purpose built boar stimulation area (DGB), direct contact with boars in gilt home pens (DBG), and fenceline contact between boars and gilts housed in individual gilt stalls (FBG). Open circles (○) represent DBG, closed squares (■) DGB, and crosses (×) FBG.

backfat thickness (18.1 ± 0.6 and 18.3 ± 0.9 mm) or estrus on which the gilts were bred (2.9 ± 0.2 and 2.6 ± 0.1). Table 2 shows the effect of the presence of a boar on breeding, quality of the breeding, total piglets born alive, and number of gilts not pregnant. Based on the objective criteria outlined, NC had a higher score than BC for both breedings ($P \leq 0.002$). However, there was no difference ($P > 0.05$) between treatments for the total number of piglets born live at term or number of gilts not pregnant.

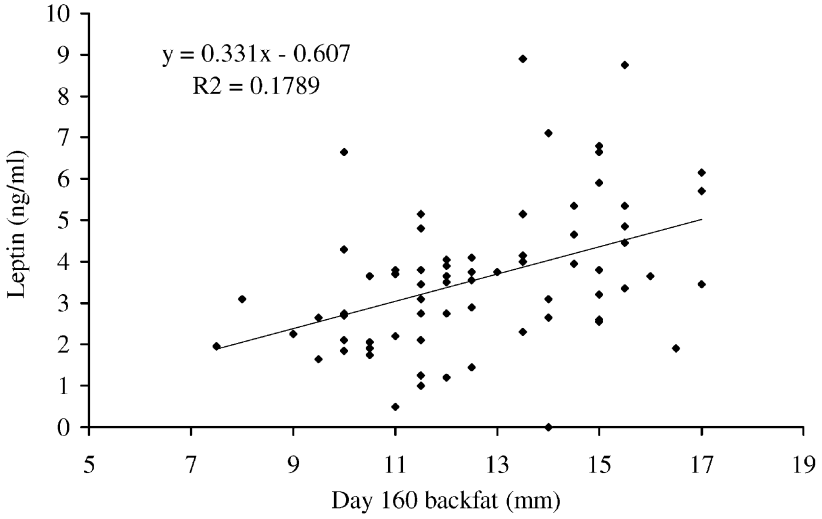

Fig. 2. Relationship between plasma leptin concentration and backfat depth at 160 days.

Table 2
Mean (±S.E.M.) breeding scores and total number of piglets born live for gilts receiving fenceline contact with a boar during breeding (BC) and receiving no boar contact during breeding (NC)

Treatment	12-Hour breed score[a]	24-Hour breed score[a]	Total live born piglets	Number not pregnant
BC ($n = 21$)	1.4 (0.2)	1.5 (0.2)	11.1 (0.6)	1
NC ($n = 14$)	2.7 (0.4)	2.9 (0.4)	10.1 (0.6)	0
P	0.001	0.002	0.20	–

[a] Breed scores—1: Excellent Breeding, gilt showed a standing reflex as soon as BPT was applied, gilt stood well for the entire breeding; 2: Very Good Breeding, gilt did not show a standing reflex as soon as BPT was applied, needed more stimulation than (1), but stood well for the entire breeding; 3: Good Breeding, gilt exhibited a standing reflex as soon as BPT was applied, but did not stand well to BPT through the entire breeding; 4: Satisfactory Breeding, gilt did not show a standing reflex as soon as BPT was applied, and did not stand through the entire breeding period; 5: Bad Breeding, gilt did not show a standing reflex as soon as BPT was applied, needed more stimulation from technician than (4) to finally elicit a standing reflex, and did not exhibit the standing reflex through the entire breeding.

5. Discussion

Previous research has concluded that daily exposure to a mature boar is a potent stimulus for the attainment of puberty [15]. Zimmerman [4] found that physical boar contact reduced age at puberty, compared to fenceline contact with a boar (184.3 days versus 197.9 days) when first boar contact occurred at 172 days. Our results confirm that puberty induction using fenceline stimulation is less effective than direct boar contact, as measured by the number of days from initial boar exposure to puberty in gilts. Also, FBG gilts were oldest at puberty, DGB gilts were the youngest, and DBG gilts were intermediate. Our results are similar to those reported by Pearce and Hughes [1], who demonstrated that gilts reached puberty at a younger age with direct boar exposure. The method of direct boar contact did not affect age at puberty, supporting the results of van Lunen and Aherne [2], who found no significant difference in age at puberty (209.9 days versus 211.8 days) or the percentage of gilts reaching puberty by 270 days (68.2% versus 47.6%) between gilts taken to the boar's pen or a boar moved to the gilts pen, starting at 140 days.

The different methods of boar exposure also affected the distribution of puberty attainment. FBG experienced a delay in the first response to puberty stimulation, as compared to DGB and DBG gilts. As reviewed by Hughes [3], the boar effect operates via a synergistic action of several boar stimuli, including visual, tactile, auditory, and olfactory stimuli. The increased days to estrus in stall-housed gilts may be due to the lack of any tactile stimulation from the boar.

The age at which gilts reached puberty varied, ranging from 163 to 210 days, at which point we terminated the experiment. The distribution of age at which gilts reached puberty was somewhat skewed to the right, probably because gilts were first exposed to a boar at 160 days of age in this experiment. If gilts were exposed to a boar at a younger age, we may have seen a more normal distribution. However, to a producer, the distribution of gilts reaching puberty is important. A more skewed distribution may be desirable, since a higher percentage of gilts will cycle sooner after first boar contact and the onset of first heat will be more synchronized [16].

Klindt et al. [17] reported that reduced prepubertal feed intake from 13 to 25 weeks of age in gilts did not adversely affect reproductive performance. These authors examined gilt efficiency as measured by quantity of feed consumed during development per live embryo in gestation and suggested that moderately energy-restricted gilts may be more efficient than ad libitum-fed gilts. Total and average feed intakes to puberty appeared to differ among treatments in our experiment, as total feed disappearance for FBG gilts was higher compared to DGB gilts, with DBG gilts being intermediate. However, FBG gilts took approximately 10 more days than DGB gilts to reach puberty.

Leptin and IGF-1 have been implicated as factors affecting the onset of puberty. However, Cheung et al. [6] suggested that leptin was not the rate-limiting determinant for puberty onset, but instead a permissive factor that allows puberty to proceed. Once the threshold of leptin is achieved, leptin may alert the reproductive system that the metabolic status is adequate to support and maintain a reproductive cycle. Hiney et al. [7,18] suggest that IGF-1 may represent one of the ''metabolic signals'' thought to be involved in the initiation of puberty, that IGF-1 circulating levels increase strikingly during puberty across a wide range of species, and that a decreased level of IGF-1 may contribute to a delayed onset of puberty. Armstrong et al. [19] demonstrated that the onset of puberty was not affected in gilts immunized against growth hormone to reduce serum IGF-1 concentrations; however, ovulation rate was reduced. Because boar exposure began at Day 160 in this trial, and we know that F1 gilts of the same genotype can reach puberty as young as 135 days [20], it is not surprising that our data did not detect a relationship between IGF-1 or leptin concentrations and age at puberty. Further, Beltranena et al. [21] demonstrated that growth rate did not affect pubertal age in gilts achieving a growth rate of at least 0.60 kg/day. Therefore, it is doubtful that growth or metabolic state limited age at puberty in the present study, because the gilts in this study would have reached the minimum growth and metabolic state necessary to attain sexual maturity.

Backfat depth was significantly correlated to blood leptin concentration at 160 days of age. These results are consistent with the data of Hamann and Matthaei [22], who demonstrated that the amount of leptin secreted from adipocytes is significantly correlated to body mass index (BMI) and percent body fat in humans, as well as the results of Robert et al. [23], who indicated that leptin expression can be associated with subcutaneous fat accumulation in pigs. However, concentration of leptin at Day 160 was not correlated with age at pubertal estrus in our study.

Several authors have demonstrated that the presence of a boar at breeding provides important stimuli that may improve reproductive performance. As reviewed by Soede [24], the duration of the standing heat response evoked by the BPT alone is shorter than the standing response evoked by the BPT when a boar is present to provide olfactory and auditory stimuli. Our data show that, using objective criteria, breedings without the presence of a boar scored lower than gilt breedings in the presence of a boar. Although litter size was not significantly different between treatments, the one pig difference in litter size would be an important economic advantage if substantiated in larger trials.

In conclusion, our data demonstrate that puberty induction using direct boar contact is more effective than fenceline contact. However, no differences existed between the two methods of direct boar contact. Further, we have demonstrated that the presence of a boar at breeding improved the quality of artificial insemination.

Acknowledgements

This research was financially supported by Alberta Agriculture Research Institute and Alberta Pork Producers Development Corporation. The authors gratefully acknowledge Jodi Hesse for her help and Genex Swine Group Ltd. for contributions to the provision of experimental animals.

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