Serologic and bacteriologic test results after adult vaccination with strain 19 in three dairy herds infected with brucellosis

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Summary: *Milk culture data and serologic test results were evaluated after adult vaccination with* Brucella abortus *strain 19 in cattle of 3 large California dairy herds infected with brucellosis. Strain-19 organisms were isolated by culture of milk from 1.9% of the vaccinated cows. Isolation of field strain of* B abortus *varied directly with magnitude of complement-fixation (CF) and rivanol titers. At time of milk culture, 74% of cows from which field strain was isolated had CF titer ≥160, compared with 58% of cows from which strain 19 was isolated. Cows with CF titer ≥160 at 2 months or ≥80 to 4 months after adult vaccination were more likely to be correctly classified as reactors (on the basis of subsequent milk culture results and/or persistently high serologic titer) than were cows with lower CF titer at these times. Cows from which* B abortus *strain 19 was isolated from milk were more likely to maintain persistent serologic titer than were cows from which neither strain of* B abortus *was isolated.*

In southern California, more than 250,000 cows are concentrated in just over 300 dairies in a 50-square mile area of the Chino Valley. These large, dry-lot dairies contain an average of 850 cows, and often share fence-line contact with 1 or more other dairies. Brucellosis has been enzootic in this area since 1972 despite a continuous eradication program based principally on test and slaughter. The combination of large herd size and herd proximity has made the task of brucellosis eradication extremely difficult. At the end of 1988, 30 herds were infected with brucellosis and most shared fence-line contact with 1 or more other infected herds.

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As the size of dairy herds increases and cattle populations become more concentrated, traditional methods of test and slaughter to eliminate brucellosis become less effective.[1] On large dairies, it is common for 1 pen of lactating or nonlactating cows to contain several hundred animals. A single abortion or calving by a cow infected with brucellosis can expose and infect many susceptible cows. Up to 15% of cows infected with *Brucella abortus* will not be detected serologically until after abortion or calving.[2] The organism has often been transmitted prior to detection and removal of infected cows from the herd. In large herds, even if individual calving isolation is implemented, it is difficult, if not impossible, to eliminate all potential exposure to brucellosis, especially if abortions occur.

In cattle, the effectiveness of adult vaccination with strain 19 to reduce the prevalence of brucellosis is well documented.[1-6] Increased immunity resulting from adult vaccination can help prevent transmission where management has failed. When all adult cattle in a herd are simultaneously vaccinated, immunity to normal exposure probably exceeds the 65 to 75% effectiveness seen after calfhood vaccination, resulting in excellent herd immunity.[2]

Adult vaccination has only recently been used as a tool to eradicate brucellosis from large dairy herds in southern California. Between 1985 and 1988, 5 herds totaling approximately 8,500 cows were adult vaccinated. During that time, adult vaccination was used only in chronically infected herds in which conventional methods of test and slaughter had failed to eliminate brucellosis. In 4 of the 5 herds, brucellosis was eradicated between 17 and 28 months after adult vaccination. In the fifth herd, replacement heifers raised on the premises, but not adult vaccinated, subsequently became infected with brucellosis, and it was necessary to vaccinate the herd a second time.

Extensive milk culture data and serologic test results were available for 3 of the 5 adult-vaccinated herds. The goals of the study reported here were to analyze these data to: determine the

frequency of *B abortus* strain-19 udder infection after adult vaccination; compare results of complement-fixation (CF) and rivanol serologic tests with results of bacteriologic testing of milk; determine whether CF test results at 2 or 4 months after adult vaccination could be used to identify cows that would subsequently be classified as reactors and sent to slaughter with acceptable rate of misclassification; and evaluate cows with positive serologic test results to determine whether cows shedding *B abortus* strain 19 were more likely to maintain persistent serologic titer than cows not shedding either vaccine or field strain of *B abortus*.

Materials and Methods

Herd selection and adult vaccination procedure—Three dairy herds, adult-vaccinated in 1987, were chosen for this study because extensive milk culture data and serologic test results were available for them. All vaccination and serologic and bacteriologic testing were done as part of the ongoing regulatory program. Herd sizes were: herd A, 800 cows; herd B, 1,950 cows; and herd C, 2,450 cows. Liquid strain-19 vaccine,[a] was diluted so that each 2-ml dose contained 5×10^8 organisms, and was administered SC. All cows were vaccinated simultaneously without regard to stage of pregnancy, and replacement heifers were vaccinated prior to entering each of the 3 herds.

Serologic evaluation—At approximately 2 and 4 months after vaccination and at monthly intervals thereafter, blood samples were taken from each cow for serologic evaluation. All samples were screened by use of the CF test, and if positive at a 1:5 dilution, were subsequently evaluated by use of the rivanol test. In herds A and B, the CF test was the only serologic test performed at 2 months after vaccination.

The rivanol test was performed according to described procedures.[7] The CF test was a manual microtitration procedure, using warm fixation, 2% RBC, 2 U of complement, and incubation at 37 C for 1 hour. Results of the rivanol test were recorded as the reciprocal of the highest dilution in which incomplete (I) or complete (+) agglutination was observed, and results of the CF test were recorded as the reciprocal of the highest dilution in which at least 25% of the complement was fixed.[8]

Bacteriologic evaluation—Milk samples from lactating cows with CF titer ≥80, were cultured 2 to 6 months after vaccination and thereafter if titer increased or persisted. Milk samples from cows with CF titer ≤40 also were cultured if the corresponding rivanol titer was high (eg, ≥1100). Multiple milk culturing attempts were performed if *B abortus* was not isolated and serologic titer persisted. Nonlactating cows meeting the aforementioned criteria were either isolated, and milk was collected for culture after parturition, or were immediately classified as reactors and sent to slaughter. To compare serologic with culture results, serologic test results from the regular herd test were paired with results of milk culturing obtained immediately after that herd test.

Quarter milk samples were collected in sterile plastic containers, placed in an ice chest, and transported immediately to the laboratory.[b] After 8 to 24 hours, gravity cream was transferred to culture plates.[9] All isolates were confirmed, and biotype was determined.[a]

Method of classifying cows as reactors by CF titer at 2 or 4 months after adult vaccination—Cows were identified that had CF titer ≥80 at 2 or ≥40 at 4 months after vaccination. Milk culture results and subsequent serologic test history of these cows were evaluated to determine whether classification by this CF titer alone, at 2 or 4 months, would have correctly identified cows that ultimately would be classified as reactors (defined later) and sent to slaughter. All cows from which a field strain of *B abortus* was isolated were classified as reactors on the basis of culture results. If field strain of *B abortus* was not isolated, cows for which serologic test history was available for 6 months or longer after adult vaccination were included in the study. These cows, whether shedding *B abortus* strain 19 or not, were ultimately classified as reactors on the basis of subsequent serologic test results. If, at the end of the observation period (≥6 months), CF titer remained >80, or rivanol titer remained >+50, cows were classified as reactors. If titers decreased or stabilized (ie, CF titer ≤80 and rivanol titers ≤+50), cows were ultimately classified as nonreactors, indicating that classification by this CF titer only, at 2 or 4 months after vaccination, was incorrect. Cows with the aforementioned stabilized CF and rivanol titers were considered safe to remain in the herd for further evaluation.

Evaluation of cows for persistent serologic titer—All cows with CF titer ≥40 that were tested by culture and from which field strain of *B abortus* was not isolated, were evaluated for persistent serologic titer. As before, cows were included in the analysis only if they remained in the herd throughout the study period and a serologic test history was available for 6 months or longer after adult vaccination. Cows not shedding field strain of *B abortus* were placed in 1 of 2 groups depending on milk culture results, either shedding or not shedding strain 19, and were stratified by CF titer at time of culture. Cows with persistent high titer were ultimately classified as reactors (ie, CF titer remained >80 or rivanol titer remained >+50). If the titers decreased or stabilized (ie, CF titer ≤80 and rivanol titers ≤+50), cows were ultimately classified as nonreactors.

[a]Provided by the National Veterinary Services Laboratory, Ames, Iowa.

[b]California Veterinary Diagnostic Laboratory System, San Bernardino, Calif.

Data management—A commercially available computerized data base manager[c] was used to record all individual cow data for each herd. Data for analysis included each cow's identification number (cow ID), serologic test date, serologic results for rivanol and CF tests, milk culture results, and if a reactor, the date branded and sent to slaughter. All data were indexed by cow ID so that each cow's serologic test history could be evaluated.

Statistical analysis—The χ^2 test for independence was used to determine whether a statistically significant difference of misclassification of reactors existed between CF titer at 2 and 4 months after vaccination. The χ^2 test for independence was also used to evaluate cows with CF titer ≥40 and tested by milk culture, to determine whether cows shedding strain 19 were more likely to develop persistent serologic titer than were cows not shedding *B abortus*.

Results

Frequency of strain-19 udder infections—*Brucella abortus* strain 19 was isolated from milk of 105 of 372 cows and replacement heifers tested by culture. Of 5,200 cows originally adult-vaccinated in the 3 herds, 98 (1.9%) were definitively diagnosed by results of milk culture as having strain-19 udder infections (Table 1). Of 360 bred replacement heifers subsequently adult vaccinated in herd A, 7 (1.9%) were also identified as shedding strain 19. Data were unavailable for the replacement heifers subsequently adult vaccinated in herds B and C.

Association of serologic test results of CF and rivanol tests with bacteriologic culture results—Magnitude of CF and rivanol titers varied directly with percentage of field strain isolates (Table 2). Cows with the highest CF titers, 640 (60%) and 320 (40%), were more likely to shed field strain than strain 19. Approximately a third (36%) of the cows with rivanol titer ≥I200 were also shedding field strain. Titers that had the greatest proportion of cows shedding strain 19 were CF 160 (44%) and rivanol I50 to +50 (43%). At CF titer ≤80, a large proportion of cows was not shedding either strain 19 or field strain of *B abortus*. Of all cows with CF titer ≥160, 139 of 187 (74%) were shedding either strain 19 or field strain of *B abortus*.

Field strain of *B abortus*, biotype 1, was isolated from 106 cows. Of 106 cows shedding field strain, 78 (74%) had CF titer ≥160 and 98 (92%) had CF titer ≥80. Because the rivanol test was not performed 2 months after adult vaccination in cows of herds A and B, rivanol titer was available for only 61 cows shedding field strain. Of 61 cows, 43 (70%) had rivanol titer ≥I200 and 55 (90%) had rivanol titer ≥I100. Although few cows with low or negative serologic test results were tested by culture in this field study, the sensitivity of CF titer ≥70 was 99% (101 of 102 cows) and of titer ≥80 was 96% (98 of 102) for detecting field strain of *B abortus* (Table 2). The sensitivity of rivanol titer I100 was 90% (55 of 61) and of titer I50 was 98% (60 of 61).

Of 105 cows shedding strain 19, 61 (58%) had CF titer ≥160, and 96 (90%) had CF titer ≥80 at time of isolation. At time of stain-19 isolation, rivanol titer was available for 74 cows. Of 74 cows, 33 (45%) had rivanol titer ≥I200 and 45 (61%) had rivanol titer ≥I100.

Most cows found to be shedding *B abortus* strain 19 were not immediately removed from the herds, and blood samples were collected during subsequent monthly tests. Of 105 cows, 93 (89%) had CF titer ≥160, and 104 (99%) had CF titer ≥80 for 1 or more tests after vaccination. Considering rivanol test results, 86 of 105 (82%) had rivanol titer ≥I200 and 96 of 105 (91%) had rivanol titer ≥I100 for 1 or more tests. In herd C, in which cows with strain-19 udder infections were allowed to remain for an extended period (approx 12 months), serologic titer was highest (determined by the

Table 1—Recovery of Brucella abortus *strain 19 from milk of cows after adult vaccination in three large California dairy herds*

Herd	No. of cows	No. culture positive	Percent (%)
A	800	17	2.1
B	1,950	34	1.7
C	2,450	47	1.9
Total	5,200	98*	1.9

*Total does not include 7 replacement heifers from herd A that were culture positive for *B abortus* strain 19.

Table 2—Comparison of complement-fixation (CF) and rivanol test results with isolation rate from milk of B abortus *after adult vaccination in three large California dairy herds infected with brucellosis*

Titer	No. of cows	Milk culture results: Field strain	Strain 19	No isol
CF				
640	58	35 (60%)	11 (19%)	12 (21%)
320	58	23 (40%)	18 (31%)	17 (29%)
160	71	20 (28%)	32 (45%)	19 (27%)
80	101	20 (20%)	34 (34%)	47 (47%)
40	56	3 (5%)	7 (13%)	46 (82%)
10-20	16	1 (6%)	0 (0%)	15 (94%)
AC	12	4 (33%)	3 (25%)	5 (42%)
Total	372	106 (28%)	105 (28%)	161 (43%)
Rivanol				
I200 to +200	121	43 (36%)	33 (27%)	45 (37%)
I100 to +100	38	12 (32%)	12 (32%)	14 (37%)
I50 to +50	49	5 (10%)	21 (43%)	23 (47%)
I25 to +25	30	0 (0%)	6 (20%)	24 (80%)
N 25	22	1 (5%)	2 (9%)	19 (86%)
Total	260*	61 (23%)	74 (28%)	125 (48%)

*Rivanol titer was not available to correlate with 112 culture results.
Number in parentheses equals percentage of culture results for each CF or rivanol titer. AC = anticomplementary. N = no agglutination at 1:25 dilution. I = incomplete agglutination. + = complete agglutination. No isol = *B abortus* not isolated.

[c]dBase III PLUS, Ashton-Tate, Torrance, Calif.

Table 3—Final classification of cows with CF titer at 2 and 4 months after vaccination with B abortus *strain 19, as determined by milk culture and subsequent serologic test results*

CF Titer	No. of cows	Final classification*	
		Reactor	Nonreactor
2 months			
640	40	38 (95%)	2 (5%)
320	41	34 (83%)	7 (17%)
160	49	41 (84%)	8 (16%)
80	69	39 (57%)	30 (43%)
Total	199	152 (76%)	47 (24%)
4 months			
640	21	20 (95%)	1 (5%)
320	25	19 (76%)	6 (24%)
160	38	31 (82%)	7 (18%)
80	39	25 (64%)	14 (36%)
40	56	14 (25%)	42 (75%)
Total	179	109	70

*Final classification of reactor are cows in which field strain *B abortus* was isolated from milk or cows that maintained persistent serologic titer (CF ≥ 160 or rivanol ≥ 1100) for at least 6 months after vaccination.

Table 4—Evaluation of persistent serologic titer in cows from which B abortus *strain 19 was isolated vs cows from which* B abortus *was not isolated after adult vaccination with* B abortus *strain 19*

CF‡ Titer	Milk culture results					
	Strain 19 isolated*			Brucella not isolated†		
	No. of cows	Persist high titer§	Low or stable titer‖	No. of cows	Persist high titer	Low or stable titer
640	11	11	0	7	4	3
320	18	18	0	14	3	11
160	31	28	3	15	5	10
80	34	24	10	40	8	32
40	7	6	1	39	9	30
Total	101	87	14	115	29	86

*Titer followed, on average, 10 months after vaccination; †Titer followed, on average, 14 months after vaccination; ‡CF titer at time of culture; §Persistent high titer includes cows that had serologic titer that remained at either CF ≥ 160 (persist) or rivanol ≥ 1100 after culture; ‖Low or stable titer includes cows that had serologic titer that decreased or stabilized at CF ≤ 80 and rivanol ≤ +50 after culture.

number of cows with CF titer >80 or rivanol titer >+50) at 7 months after adult vaccination.

Classifying cows as reactors with CF titer at 2 or 4 months after adult vaccination—At 2 months after adult vaccination, if all cows with CF titer ≥80 had been classified as reactors, 47 of 199 (24%) would have been misclassified on the basis of culture and subsequent serologic test results (Table 3). However, 30 of 69 (43%) cows with CF titer of 80 would have been misclassified. If cows with CF titer [G>]160 were classified as reactors, only 17 of 130 would have been misclassified, and the ra e of misclassifications would have decreased from 24% to 13%. A statistically significant difference was evident between misclassification rates of cows with CF titer of 160 or 80 at 2 months ($\chi^2 = 9.67$, $P < 0.005$). Differences were not observed between any of the other CF titers.

At 4 months after adult vaccination, if all cows with CF titer ≥40 had been classified as reactors, 70 of 179 (39%) would have been misclassified and 38 of 56 (68%) cows with CF titer of 40 would have been misclassified. If all cows with CF titer ≥80 were classified as reactors, 28 of 123 would have been misclassified and the rate of misclassifications would have decreased from 39% to 23%. A statistically significant difference was apparent between misclassification rates of cows with CF titer of 80 or 40 at 4 months ($\chi^2 = 14.53$, $P < 0.005$), but differences were not observed between any other CF titers.

Evaluation of cows for persistent serologic titer—The CF and rivanol test results were followed for an average of 10 months for 101 cows shedding strain 19, and for an average of 14 months after adult vaccination for 115 cows with CF titer ≥40 at time of culture and from which *B abortus* was not recovered from milk (Table 4). Shedding of *B abortus* strain 19 in milk was associated with persistent serologic titer. Of 101 cows shedding strain 19, 87 (87%) compared with 29 of 115 (25%) cows not shedding *B abortus*, were ultimately classified as reactors because of persistent serologic titer. Cows that were shedding *B abortus* strain 19 in milk were more likely to maintain persistent serologic titer for an average of 10 months after adult vaccination, than were cows that were not shedding *B abortus* ($\chi^2 = 80.27$, $P < 0.005$).

Discussion

In a Florida study,[10] it was reported that of 14,789 cows given the reduced dose of strain 19 SC, only 66 *B abortus* strain-19 udder infections resulted (0.45%), compared with 21 of 2,531 (0.83%) cows given the standard dose. In our study, the percentage of cows confirmed by culture results as shedding *B abortus* strain 19 after adult vaccination (1.9%) was approximately 4 times that reported in cows given the reduced dose vaccine (0.45%) in the large dairies in Florida. The dose of vaccine used in California (0.5×10^9 CFU) was less than the reduced dose used in Florida (3.0×10^9 CFU).

Several factors may have contributed to the higher rate of strain-19 udder infections and persistent serologic titer in California dairy cattle, compared with Florida cattle. Although all southern California dairy cows were calfhood vaccinated, many were vaccinated at ≤3 months of age, and it has been speculated that they have reduced immunity to brucellosis. Many of the herds in which the calves were vaccinated at ≤3 months of age have experienced high rate of brucellosis abortions, as well as high reactor rate (eg, ≥25% of the herd in 1 year). If cows are vaccinated against brucellosis as calves, they are less susceptible to udder infections and persistent serologic titer when vaccinated with strain 19 as adults. Prior calfhood vaccination with strain 19 had the effect of reducing significantly the proportion of cattle with persistent CF titer after adult vaccination.[11] Attempting to culture milk samples as early as 2 months

after adult vaccination may also identify a greater number of cows shedding strain 19 than if culturing is delayed for a longer period, as was possibly the case in the Florida study. Other factors contributing to an increase in strain-19 udder infection and persistent serologic titer may be the stress of close confinement, crowded conditions, and high milk production in the dairy herds of southern California.

The rate of cows recovering from strain-19 udder infection, as indicated by decreasing or stabilized titer, was 14% (14 of 101 cows) at an average of 10 months after vaccination. This was less than the 40 to 65% recovery rate 6 to 12 months after isolation reported from Florida.[10] Comparison of periods between California and Florida appear to yield similar results, because it was reported that milk samples in Florida were taken for culture at 2 to 6 months after vaccination and thereafter. However, the range for sample collection in Florida could be from 8 to 18 months after vaccination, which may explain a higher recovery rate than that in California. In this study, culture attempts were not made prior to removing cows as reactors and it is not known whether these cows were still shedding strain 19. It is likely that more cows would have had decreasing or stabilized titer had they remained in the herd for a longer period.

A small percentage of cows with persistent serologic titer, whether shedding strain 19, can represent a substantial number of cows in large dairies. In this study, culture of milk samples from 1.9% (98 of 5,200) of adult-vaccinated cows yielded strain 19. In addition, approximately 40 cows with CF titer $\geq$80, many in their last trimester of pregnancy, were sent to slaughter without having milk cultured and were not included in this study. On the basis of the known culture results from this study, half or more of these 40 cows likely had serologic titer resulting from vaccination. In addition, 29 cows included in the study maintained persistent high titer (Table 4) even though *B abortus* was not isolated, many likely the result of vaccination. Therefore, the rate of cows becoming infected with strain 19 or maintaining persistent serologic titer attributable to adult vaccination can be estimated to be between 2 and 4%.

Interpretation of serologic titers in an infected herd after adult vaccination is substantially aided by use of supplemental serologic testing. The rivanol and CF tests are advantageous because they are as sensitive as the card test but are more specific.[12] One study[8] found comparable sensitivity of the card, rivanol, and CF tests in adult-vaccinated cows, but found the CF test to have the highest specificity. In California, the CF test has proven to be the most useful screening test for the first year after adult vaccination.

Shedding of field strain or strain 19 in milk correlates to the amount of *Brucella* antibody.[8] One study[12] found the greatest percentage of *Brucella* isolations from milk of cows with CF titer of 80 (the highest titer tested). In a large study[8] done to correlate serodiagnosis and isolation of *B abortus* from quarter milk samples after adult vaccination, field strain was not isolated more frequently than strain 19 until rivanol titer of 1200 was reached or CF titer exceeded 4+ at dilution of 1:40. In this study, field strain of *B abortus* was not isolated more frequently than strain 19 until CF titer of 320 was reached or rivanol titer reached 1200.

Concurrent bacteriologic evaluation of quarter milk samples is desirable but not always practical, especially when dealing with large herds and large numbers of reactor and suspect titers. In herds with high prevalence of *B abortus* field strain infection, as was the case in the 3 herds in this study, CF titer at 2 and 4 months after adult vaccination can be used as a guideline to classify cows as reactors for removal to slaughter. In one study,[13] rivanol and CF test results at 2 months after adult vaccination with strain 19 proved valuable for management of the herd to eliminate brucellosis. In the same study, rivanol titer of 100 and CF titer of 80 at 2 months were indicators of infection, and if all test-positive cattle at 2 months had been slaughtered, 4% of the total vaccinated cattle would have been slaughtered unjustly.

For these 3 herds, the use of CF titer $\geq$160 at 2 months and $\geq$80 at 4 months after adult vaccination were found to be good guidelines to begin classifying reactors at these specific periods without overly misclassifying cows that were not infected with field strain of *B abortus*. However, from current experience, after adult vaccination of 19 additional large California dairy herds, it has been speculated that if the prevalence of brucellosis in the herd is low, and the rate of strain-19 udder infection and postvaccinal titer is greater than the expected 2 to 4% as seen in these 3 herds, removing all cows at 2 and 4 months, using the aforementioned CF titer guidelines, may incorrectly classify noninfected cows as reactors. In these cases, culture results are helpful prior to final reactor classification.

Aggressiveness of reactor classification by serologic test results alone will depend on the overall serologic titer response of the herd, and the prevalence of field strain *B abortus* at time of adult vaccination. A good compromise is to use serologic test results at 2 and 4 months after vaccination to immediately classify as reactors, and send to slaughter pregnant cows in late gestation that are at risk of aborting or calving. Culture of milk can then be performed for nonpregnant cows and cows <5 months pregnant that are not immediately at risk of transmitting brucellosis. If culturing is to be performed, the first cows tested should be those in late gestation that are of greatest risk to abort or calve. In large dairy herds, a substantial number of

cows infected with strain 19 or maintaining persistent serologic titer may greatly concern the herd owner, even if only 2 to 4% of the herd is affected.

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Book Review: Cattle Embryo Transfer Procedure

In writing this basic training manual for ranchers, dairymen, artificial insemination technicians, animal scientists, and veterinarians, the author's purpose was to explain and/or illustrate all elements for a successful bovine embryo transfer (ET) program. At the end of the preface is the following note: "In some states, providing embryo transfer service on a fee basis for clients is restricted to veterinarians only. Check with the state attorney general's office for details." Seven chapters cover Cattle Management, Recipient Synchronization, Donor Superovulation and Artificial Insemination, Embryo Recovery, Embryo Handling, Embryo Freezing, and Embryo Transfer. Five appendices include information on embryo collection and transfer supplies and products, embryo freezing and artificial insemination supplies and products, pharmaceuticals, and miscellaneous certificates and forms, and embryos and ovaries.

The author has briefly and concisely outlined procedures contributing to bovine embryo transfer that he has found to be successful. The manual provides useful information for students and graduate veterinarians contemplating bovine ET involvement or for anyone with a desire to become familiar with some of the approaches used in current ET practice. Professionals concerned with broader aspects of ET technology and cattle breeding, along with experienced embryo transfer practitioners, will expectedly consider this account of cattle embryo transfer procedure to be overly abbreviated. Many illustrations greatly enhance the descriptions, but in some instances, greater clarity in their printing would be desirable. The usefulness of this instructional manual in embryo transfer for the novice should well justify its modest price.—[*Cattle Embryo Transfer Procedure. By John L. Curtis. 131 pages; illustrated. 1991. Available in US from Academic Press Inc, San Diego, CA 92101. Price $29.95.*]—BENJAMIN G. BRACKETT