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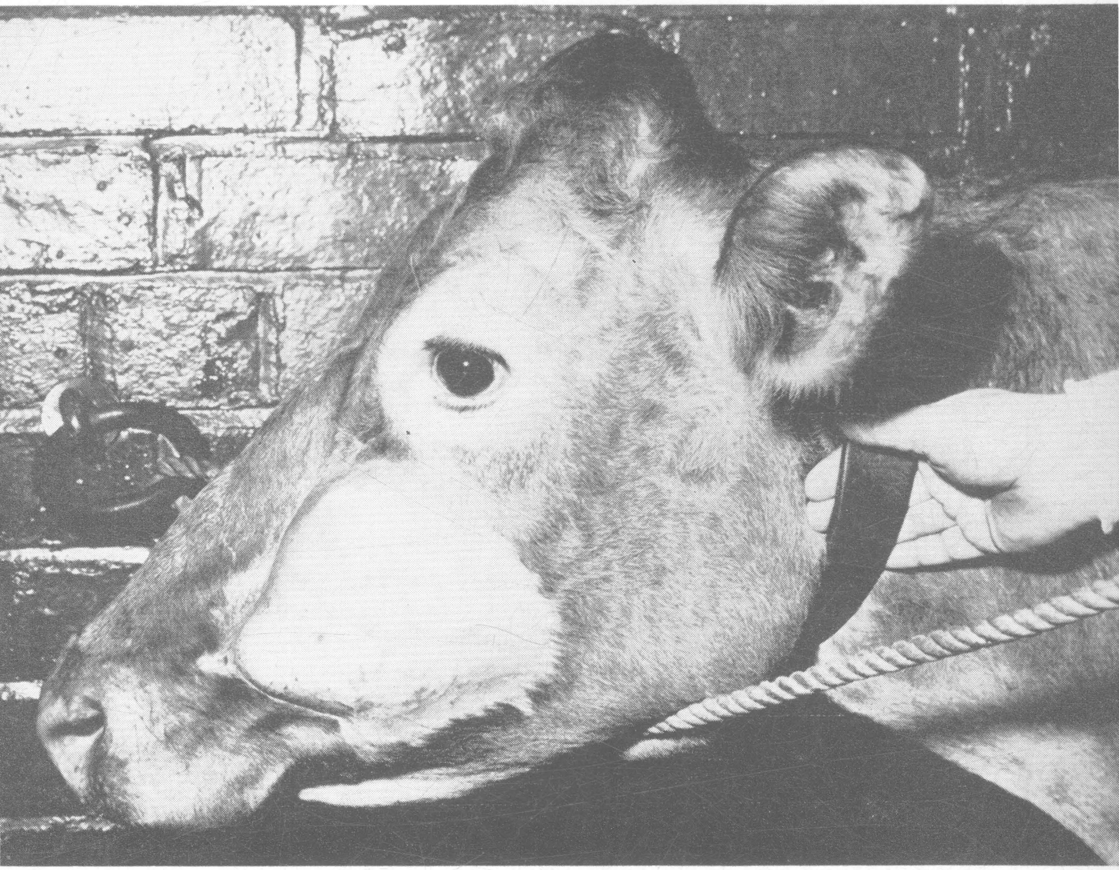

Genetic Aspects of Actinomycosis and Actinobacillosis in Cattle

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Cover photo: An early case of lumpy jaw (actinomycosis) affecting a facial bone of a dairv cow.

Genetic Aspects of Actinomycosis and Actinobacillosis in Cattle

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INTRODUCTION

Actinomycosis is a disease that causes tumor-like swellings in the jawbones of cattle (cover photo). Actinomycosis is commonly called lumpy jaw and usually involves the lower jaw. The bony enlargement that it causes is characterized by formation of pus cavities (abscesses) and tracts in the infected spongy bone (Figure 1). Pus often drains to the outside through the skin covering the spongy bone. Small hard yellow sand-like granules are present in the pus from infected bones. These granules can be crushed, stained, and identified under the microscope as the cause of the disease. This condition and actinobacillosis (wooden tongue) were thought to be a single disease before 1930 and still are termed so popularly in the absence of clinical diagnosis. It was recognized then that infections of the soft tissues (lymph nodes, lungs, tongue, etc.) were caused by *Actinobacillosis lignieresi,* and the disease was called wooden tongue or actinobacillosis (Figure 2). Actinomycosis, on the other hand, is responsible for lesions of the bone in cattle and moose, and is caused by *Actinomyces bovis.* Although the specific nature of the causative agent of actinomycosis is not completely known, it is generally believed to be a fungus.

REVIEW OF LITERATURE

Actinomycosis occurs throughout the world (7)[1]. The organism of lumpy jaw was first observed in 1877 by Bollinger (5) and Harz (cited by Merchant, 23), who first described it and suggested the name *Actinomycosis bovis.*

The mode of infection with *A. bovis* is not definitely known, although the organism has been recovered from the mouths of apparently normal cattle (7, 11). It is probable that organisms enter tissues of the jaw through the alveoli of teeth or through injured mouth mucosa (14).

[1] Numbers in parentheses refer to Literature Cited.

Thomassen (32) reported that wooden tongue of cattle responded to potassium iodide treatment. Nocard (26) distinguished the organism causing "farcin du boeuf" and confirmed this observation. Norgaard and associates of the USDA cured 96 of 100 cases of lumpy jaw in cattle from the Chicago stockyards, as reported by Salmon (27). Two animals among 40 in this trial still had internal actinomycosis lesions on examination. The bone had not been involved in animals that recovered.

Lignieres and Spitz (21) isolated *Actinobacillus lignieresi* from lesions resembling lumpy jaw among infected cattle in Argentina. They called this condition affecting the skin and soft tissues actinobacillosis. Dawson (10) mentioned that actinomycosis affected various parts of the body in man, cattle, horses, sheep, and swine, but occurred more often among cattle. He used potassium iodide treatment successfully. Higgins (16) found *A. lignieresi* in soft tissues and lymph nodes of affected cattle. Wright (36) isolated branching filamentous microorganisms from 13 cases of actinomycosis in man and two in cattle.

Salmon (27) mentioned that Rivolta had observed actinomyces in tumorous tissues as early as 1860 without regarding them as the causative agents. Israel (19) and Wolff and Israel (34) found the same fungus in man under the skin, in mucous linings, tongue, sometimes in lungs, and in the jaw bone ultimately. Griffith (13) found typical granules of the soft tissue actinobacillosis in beef tongues imported from Argentina, North America, and Siberia, as well as in 44 tongues obtained in England. Forty cases were distinguished by Gram stain as actinobacillosis and four as streptothrix or the fungus type. Connaway (8) mentioned the ray fungus (in pus) of lumpy jaw in cattle. He did not distinguish the condition from wooden tongue, though he reported yellowish sore spots with well-defined margins in the mouth.

Bosworth (6) examined soft tissues of 21 cattle from the Islington market affected with actinobacillosis, and 12 cases with jaw bones and sometimes overlying soft tissues involved with streptothrix. He reported:

> When the streptothrix invades the bone it produces in its immediate vicinity a rarefying ostitis. In parts a little more remote from it there is a tendency to the formation of new bone. . . . the bone becomes expanded and more porous in character. The spaces in its interior become widened and filled with a soft greyish or pinkish granulation tissue in which the characteristic greyish or yellowish-white granules are more numerous. This tissue tends to become semi-purulent or even purulent.

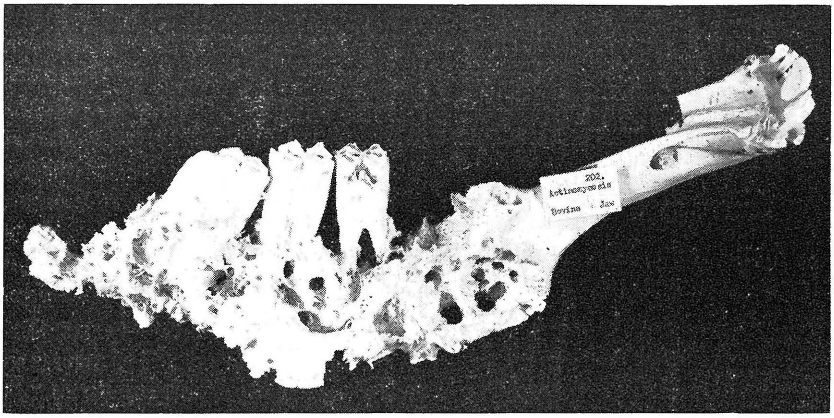

Figure 1.—An advanced case of lumpy jaw (actinomycosis) with tracts in the spongy bone of the right lower jaw.

Figure 2.—An advanced case of wooden tongue or actinobacillosis in a beef animal.

> The cheek lesions take the form of a diffuse fibrous thickening in which are found patches of soft tissue similar to that found inside the bone and sometimes continuous with it at places where the bone has been removed. The skin over this thickened area is very adherent, and it may show ulcerations at some points where fistulous canals open on to the surface and discharge a yellowish-white creamy, non-glutinous pus containing colonies of the organism. . . . the granulous tissues (sometimes) form a soft fleshy, projecting mass, often pedunculated and of mushroom shape.

The cases of actinobacillosis involved fifteen head glands, eight jawbones, seven soft tissues of the cheek and intermaxillary space, four in the tongue, and one each of the hard palate and interior of the pharynx. He described cases of actinobacillosis in soft tissues of the head thus:

> . . . soft granulation tissue of a greyish or yellowish color, which contained typical granules and were surrounded by a capsule of connective tissue. These nodules increase in size and their interior becomes semi-purulent and ultimately breaks down into actual pus, while the fibrous tissue around them continues to develop. The glands consequently become much enlarged and their normal substance entirely disappears. The pus they contain is greenish-white or greenish-yellow in colour, thick and viscid or glutinous in consistency, and contains the typical granules, which are ordinarily greyish and semi-translucent. Occasionally they are calcified, especially in the jaw lesions, and they then become yellowish-white and opaque.
>
> In the tongue were found firm nodules of the size of a pea embedded under the epithelium, which are sometimes shed, having irregular patches of ulceration. Around the nodules there was a diffuse increase of connective tissue, the presence of which gave to the affected parts a firmer consistence than normal. The nodules themselves were formed of a dense fibrous capsule enclosing soft material in which colonies were numerous.

Davis and Torrence (9) believed before 1930 that the disease of the soft tissues and that typified by rarefying ostitis in bones (with macroscopic actinomycosis granules in the pus) were not the same disease. The latter involved infection of the jawbone and adjacent soft tissues by *Streptothrix actinomyces* (34).

Thompson (33) cultured *Actinomyces bovis* and *Actinobacillus lignieresi* separately from affected cattle in the United States. *A. bovis* caused lesions of the bone and was due to a Gram-positive rod-shaped or filamentous organism growing best under reduced oxygen tension. *Actinobacillus lignieresi* (the cause of wooden tongue) was a small Gram-negative non-motile rod growing best under aerobic conditions. Wooden tongue in Europe apparently was due wholly to it.

Smith and Jones (29) distinguished causes of lumpy jaw as *A. bovis* which ultimately involved the jawbones and/or skull, and *Actinobacillus lignieresi* that infected the skin, lymph nodes of the head and neck, and other soft tissues. Clinically, according to Shahan and Davis (28), actinomycosis or lumpy jaw in cattle included hard swellings of the tongue and other organs (wooden tongue) as well as bony enlargements of the jaw. They mentioned that intravenous sodium iodide injections were practically specific for actinobacillosis, but some question remained as to effectiveness with *actinomyces* which involved the bony tissues. They distinguished these organisms microscopically and culturally from materials examined from 80 infected cattle.

Monlux and Davis (25) recommended separation of affected cattle to prevent pus discharges from contaminating feed, water, bedding, or abrasions of the skin of healthy animals. They stated that *A. lignieresi* (which infected soft tissues) responded to medication with antibiotics, iodides, and sulfanomides, as well as to surgery in the early stages. Hagan and Brunner (14) described pathogenicity of *Actinomyces bovis* and *Actinobacillosis lignieresi* and mentioned that they respond to different treatments.

Mohler and Shahan (24) indicated that the frequency of animals being condemned in whole or part was increasing at the time, partly due to expanding meat inspection services. In 1936, parts of carcasses of 1.34 percent of cattle and calves were condemned for lumpy jaw. One carcass in 11,912 (0.0084 percent) was wholly condemned. However, frequencies had dropped in 1961 (1) to 1.19 percent for partial condemnation, and 0.0024 percent for total condemnation. The two types of the condition have not been reported separately.

Lumpy jaw among bulls in natural and artificial service in the United States and Canada was given by Becker, *et al.* (3) as the leading disease condition for disposal of these animals. The incidence was 3.69 percent of bulls in natural service born prior to 1941. The proportion was 1.80 percent of bulls removed from artificial service in 1954-59 (2).

Evaluation of genetic effects with diseases of known causative agents presents special problems. Frequencies are generally low, making it difficult to accumulate sufficient data to make reliable estimates. Where many farms or studs are involved, management practices vary considerably, and this may affect the frequency of the condition. With the tendency for related individuals to be on the same farm, a common environment for relatives could lead to environmental correlations which might be mistaken for genetic effects.

There are numerous reports of susceptibility to specific diseases being genetically influenced, however. These involve small and large animals and birds (18). With large animals in a single herd, some of the evidence is admittedly meager. With cattle, evidence of genetic effects on mastitis (20, 22), tuberculosis, protozoan diseases, foot and mouth disease, and several others (18) has been reported. The mechanisms of these apparent differences in ability to resist disease are even less understood. Biochemical aspects of several diseases, mostly with humans, have been evaluated to some degree, such as reviewed by Sutton (31).

Two preliminary reports of this investigation have been presented (4, 12).

PLAN OF INVESTIGATION

The useful tenure and causes of losses of dairy bulls in natural service have been investigated for several years (3), with similar study of dairy and beef bulls in artificial use (2). Reasons for removal or causes of death of these animals were stated by herdsmen or owners, and often were based on veterinary diagnosis. The records represented a sample of leading dairy bulls in Canada and the United States. Records of 16,261 bulls were available, in addition to case studies from several cooperating dairy herds.

To investigate lumpy jaw among females, a survey was made through the cooperation of dairymen in Ohio for information on frequency, age of occurrence, and other aspects. Additional records were obtained from case histories in selected herds.

The objectives of this investigation were (a) to establish the frequency and distribution of lumpy jaw, and (b) to analyze for possible genetic influences.

RESULTS

Lumpy Jaw in Dairy and Beef Bulls

Of the 15,867 bulls of the five major dairy breeds and Milking Shorthorns, 341 or 2.15 percent were discarded or died of lumpy jaw. No lumpy jaw was reported among 12 Red Danes. Five cases were reported among 382 (1.31 percent) beef bulls. With these limited numbers, there was no evidence of a difference in frequency between beef and dairy bulls.

TABLE 1.—FREQUENCY AND AGE OF DISPOSAL OR DEATH OF MALES AFFECTED WITH LUMPY JAW.

	Ayrshire	Brown Swiss	Guernsey	Holstein	Jersey	Milking Shorthorn	Combined
			Total Number of Males				
Age	1,467	1,075	4,079	5,369	3,525	352	15,867
			Lumpy Jaw Males				
9 months	—	—	1	—	—	—	1
1 year	—	—	3	—	—	—	3
2 years	—	1	6	2	3	—	12
3 years	3	1	18	2	4	—	28
4 years	3	—	37	10	2	—	52
5 years	3	—	47	5	8	—	63
6 years	—	1	25	3	6	—	35
7 years	—	—	19	3	4	4	30
8 years	1	1	32	3	3	1	41
9 years	1	1	25	3	4	2	36
10 years	1	—	11	1	2	—	14
11 years	—	1	11	1	2	—	15
12 years	—	—	6	—	1	—	7
13 years	—	—	2	—	—	—	2
14 years	1	—	—	1	—	—	2
Total	13	6	243	33	39	7	341
Frequency	0.89%	0.56%	5.96%	0.61%	1.10%	1.99%	2.15%

The frequencies of lumpy jaw for six breeds, listed in Table 1, were subjected to chi-square analysis. Differences among these breeds were significant (P < 0.001), obviously due to the high frequency among Guernseys. When the five single degrees of freedom were evaluated, only the comparison of Guernsey versus other breeds was significant (P < 0.001), as shown in Table 2.

The youngest animal disposed of for the condition was a nine-month-old calf. Animals with the condition(s) were removed at various ages, the majority between three and nine years. It was evident that some older affected animals were housed separately, and used in service until advanced age. Ages at disposal or death of affected bulls also are presented in Table 1.

TABLE 2.—ANALYSIS OF DIFFERENCES AMONG BREED FREQUENCIES OF LUMPY JAW.

Breed Comparison	Degrees of Freedom	Chi-square
2 vs 4	1	0.014
1 vs 2, 4	1	0.449
5 vs 1, 2, 4	1	2.338
6 vs 1, 2, 4, 5	1	2.311
3 vs 1, 2, 4, 5, 6	1	378.635**

* Breeds are: (1) Ayrshire, (2) Brown Swiss, (3) Guernsey, (4) Holstein, (5) Jersey, and (6) Milking Shorthorn.
** P < 0.001.

No attempt was made in the early years of the investigation to distinguish between the soft tissue and bone type of infection, except as volunteered by cooperators at the time. During the last two years of the investigation, however, an attempt was made on recently disposed individuals, where type of the disease had been diagnosed. Of 341 cases reported in Table 1, 48 were distinguished as to type of infection, 20 being in the soft tissue, and 28 in the bone. Method of disposal was known in 171 cases; 138 were sent to market (at least two of these were condemned), 20 died, and 13 were sacrificed.

Pedigree Study

Reasons for disposal of direct and collateral relatives of lumpy jaw bulls were known in many cases. A pattern of lumpy jaw seemed to exist among these relatives. In a few cases, related individuals contracted lumpy jaw at the same farm or stud at about the same time. More frequently, however, several years elapsed between observed cases. The related animals were at different locations in many instances, even in different states. Relationships and other pertinent data have been summarized by breed.

Ayrshires.—There were 1,467 life records of Ayrshire bulls; 13 or 0.89 percent had lumpy jaw when discarded. One of them died and two were removed when unable to eat or drink. Five of the affected animals were related closely. They included a sire, two sons, and two grandsons (full brothers). The dam of the full brothers had a paternal brother with the condition. One was known to have been bone-type, but type of infection was not stated for the others.

Brown Swiss.—Six Brown Swiss bulls were removed for lumpy jaw among 1,075 recorded. One bull had a son and grandson affected. Other relationships were too distant to indicate a related source. One of these bulls died of wooden tongue (actinobacillosis) when 2.7 years old. One bull had the jaw and teeth sockets affected, doubtless the bone type.

Guernseys.—Of 4,079 Guernsey bull records in this phase of the study, 243 were reported with lumpy jaw. Many of the cases occurred among closely related animals. A cow and her full brother were in the pedigrees of many affected bulls. There were frequent cases in certain family lines, largely independent of the herd or area in which the animals were located at time of disposal. The bull above started a line of five bulls in four consecutive generations, all with the bone-type actinomycosis. Although they were bred on one farm, these five animals were used terminally on four separate farms. Seven pairs of sires and sons were affected. In 15 instances, a bull and his grandson had the condition. Another bull, his sire, and both grandsires were affected. Eleven bulls had two affected sons each, and two bulls had three sons each with the condition. Two dams had two sons each that were affected. Eight Guernseys were stated to have had the soft tissue (bacterial) type of lumpy jaw, and 20 had the bone-type. It was stated that two of the latter did not respond to treatment.

Cases of lumpy jaw occurring within family lines are summarized in Table 3. Bull A was used until 12 years old, when he became sterile. Bull C was killed and buried when 4.4 years of age, the reason not being known by persons later managing this farm. Bull D was removed at 5.9 years for an active case of lumpy jaw, and sired one son reported with the condition. Bull E was not reported as a lumpy jaw case. His usefulness as a breeder terminated at 15.9 years of age with an abscess in the lung, the cause of which was not stated. Bull F was killed because of impotency a year after his last productive natural service at 12.8 years of age. Bull G lived over 4 years after his last productive service. The imported bull H died at 11.7 years of age, being sterile at the time. The imported bull I was discarded for sterility at 11.5 years of age. These eight bulls and one full sister had 8 sons, 38 grandsons, 58 great-grandsons, and 41 in the next two generations reported with lumpy jaw.

TABLE 3.—OCCURRENCE OF LUMPY JAW IN SEVERAL GUERNSEY LINES.

Parent	Generation				
	1	2	3	4	5
Bull A	1	5	4	2	—
Cow B*	0	5	14	10	4
Bull C	1	5	12	4	4
Bull D	1	0	1	1	—
Bull E	1	7	4	—	—
Bull F	2	1	9	3	1
Bull G	0	4	10	5	5
Bull H**	0	4	3	2	—
Bull I**	2	7	1	—	—
Total	8	38	58	27	14

* Full sister to Bull A.
** Imported bulls.

Holstein-Friesians.—Thirty-three cases of lumpy jaw were reported among 5,369 Holstein bulls (0.61 percent). Cases occurred in two paternal brothers on the same farm, with nearly a three-year interval between tenures. Two affected bulls were bred and kept on one farm for over two years. They were by the same sire, and the dam of one was a full sister to the other's maternal granddam. The sire of these two bulls also appeared as maternal grandsire of a lumpy jaw bull in another state. Other family names occurred in common only in the third or fourth generation, and with little consistent connection in this large population of bulls.

Jerseys.—Analysis of the records of 3,525 Jersey bulls revealed 39 (1.10 percent) cases of lumpy jaw. Ten cases were distinguished as affecting soft tissues and three with bone affected.

Five cases were among descendants of one bull imported from the Island of Jersey and in service to past 16 years of age. Reason for his disposal was not stated by the manager. An imported son was operated on for soft tissue lumpy jaw affecting the throat. Another son that became affected was born on this farm one month before the throat operation on the first son, and two months after the sire's last productive service. Another son (full brother to the first son) was in another state when removed for lumpy jaw. A fourth case in this family (also soft tissue) was reported in a grandson. A fifth case occurred in a great-grandson.

One large Jersey family included 10 affected bulls born over a 33-year period and distributed in eight states. Despite this wide distribution, two were grandsons and one a great-grandson of one bull. One cow was the granddam of one case and great-granddam of another affected bull. Four of these 10 individuals were included in the closely related animals of the preceding paragraph.

A bull and his grandson had lumpy jaw. Although on the same farm, 2.3 years intervened between slaughter of the older bull and birth of the grandson. Another bull in which "abscesses caused sterility" when 12.3 years old had one son that was discarded for lumpy jaw when 11.3 years old. Two grandsons (paternal brothers) were discarded with the same condition in different states. One was recognized as the soft-tissue type. Two great-grandsons also had lumpy jaw. In another line, two paternal brothers had lumpy jaw. Their paternal grandsire was the double great-grandsire of another case. Two of these affected animals were used for a short time on one farm, with a short interval between tenures.

Milking Shorthorns.—Of 352 completed records of Milking Shorthorn bulls, seven individuals were removed for lumpy jaw, one diagnosed as affecting the jaw bone. Three lumpy jaw bulls were paternal brothers, owned in two different states.

Beef Breeds.—Some 382 records of disposals of beef bulls included two lumpy jaw cases among 156 Angus (1.38 percent), two of 176 Herefords (1.14 percent), one of 45 beef Shorthorns. Three Brahman and two Red Poll bulls were unaffected. Type of infection in these five cases was not reported.

Lumpy Jaw Among Ancestors of Affected Bulls

An attempt to quantify possible genetic effects was made with Guernsey bulls. There were 87 cases among bulls used in artificial insemination. A control group of 85 Guernseys serving in the same studs at the same time was assembled. Reasons of disposal were available on about 60 percent of the seven nearest male ancestors of these two groups of bulls. The frequency of lumpy jaw among male ancestors of lumpy jaw bulls was 10.0 percent, as compared to a frequency of 6.7 percent among ancestors of the control group. Chi-square analysis showed this difference to have a level of probability of about 0.15.

An Area Survey for Prevalence of Lumpy Jaw Among Cows

Registered Guernsey and Holstein herds in Ohio were surveyed for prevalence of lumpy jaw. Some 600 members of the state Guernsey association and 2,600 members of the state Holstein-Friesian association were surveyed through cooperation of these organizations. Identical letters accompanied the questionnaire pointing out that no herd would be identified, this part being confidential. The form requested information on numbers of cows in the milking herd as grouped by age: one, two, three, four, five, six, and seven years or older; numbers of animals in the milking herd that had lumpy jaw, were blind, or were tailless; and the age of each animal in these categories. Questions concerning tailless and blind animals were included so that a comparison could be made with abnormalities of low frequency. It was hoped that thus an unbiased estimate of frequency of all three conditions would result. All questions and blanks for appropriate responses were on a return-addressed post card. Signature was voluntary.

Useful returns were received from 706 Holstein and 161 Guernsey breeders reporting on 24,185 and 4,997 cows respectively. The records were summarized and analyzed statistically using either the log-likelihood ratio (G) test (35), or the chi-square test of heterogeneity (30), when large numbers made the G-test more cumbersome. Differences between the two breed means in age composition were tested by the "t" test (30).

Results of Survey.—Reliability of results based upon comparison of information gathered from the separate surveys depends on comparability of the two sets of returns. The proportion of useful questionnaires returned (27.1 and 27.3 percent by Guernsey and Holstein breeders, respectively) did not differ significantly between breeds. The proportion of respondents who signed the reports was not different for the breeds (70.4 percent for Holsteins and 65.9 percent for Guernseys).

It had been determined previously (15, 17) that tailless and blindness were not highly heritable in cattle and were, like the occurrence of lumpy jaw, relatively uncommon. Calves born with these conditions usually are eliminated from the herd so that most of those that occur in cows of milking age are attributable to accident or disease. Much of the unilateral blindness reported was ascribed to a prior infection of pink eye, i.e., contagious conjunctivitis. It was anticipated therefore that the frequencies of these two conditions should not differ materially between breeds, and that if they did, bias should be suspected in the report for lumpy jaw, the characteristic of primary interest. It can be seen in Table 4 that frequencies of blindness and taillessness were low in both breeds, and in neither case did the chi-square value reach a significant level. This indicated that occurrence of these two conditions was not different in the two breeds sampled.

There was no reason from these analyses to suspect that samples from the two breeds were not comparable or that any breed differences for lumpy jaw would be attributable to biased samples.

Analysis of the reports on 24,185 Holstein cows revealed that 35 (0.14 percent) were affected with lumpy jaw (Table 4); 21 of 4,997, or 0.42 percent, of the Guernsey cows were afflicted.

TABLE 4.—FREQUENCY OF BLIND, TAILLESS, AND LUMPY JAW COWS REPORTED BY BREEDERS.

Breed	Total Cows	Afflicted Cows					
		Blind*		Tailless*		Lumpy Jaw**	
	(No.)	(No.)	(%)	(No.)	(%)	(No.)	(%)
Holstein	24,185	56	0.23	25	0.10	35	0.14
Guernsey	4,997	16	0.32	3	0.06	21	0.42
Total	29,182	72	0.25	28	0.10	56	0.19

* Breed frequencies not significantly different
** Breed frequencies different ($P < 0.0005$).

The chi-square value associated with this three-fold difference in frequency of the disease has a probability value of $P < .0005$.

TABLE 5.—AGE DISTRIBUTION OF GUERNSEY AND HOLSTEIN COWS SURVEYED.

Years	Guernsey*		Holsteins*	
	(No.)	(%)	(No.)	(%)
2	918	18.4	4,643	19.2
3	950	19.0	4,716	19.5
4	799	16.0	4,142	17.1
5	686	13.7	3,537	14.6
6	557	11.2	2,843	11.8
7+	1,087	21.8	4,304	17.8
Total	4,997	100.0	24,185	100.0

* Breed differences in age distribution significant ($P < 0.0005$).

This highly significant breed difference might be associated with factors primarily non-genetic in origin, such as a difference in average tenure in the milking herd or different geographical distribution, so that more cows of one breed were in contact with more of the causative organisms than those of the other breed. To investigate possible relation of age to lumpy jaw, age distributions of cows of each breed were tabulated in Table 5. Guernseys had a smaller proportion of animals in each of the younger groups than did the Holsteins. However, the incidence of lumpy jaw at various ages in the two breeds did not exhibit significant heterogeneity, as shown in Table 6. Affected Holsteins had a mean age of 4.9 years and a standard deviation of 2.69 years; affected Guernseys, a mean age of 4.7 and a standard deviation of 1.77 years. Neither the mean difference nor the difference between variances was significant,

TABLE 6.—AGE DISTRIBUTION OF COWS WITH LUMPY JAW.

Years	Guernseys*	Holsteins*	Combined
2 and 3	5	12	17
4 and 5	11	7	18
6 and 7+	5	12	17
Total	21	31	52

* Breed differences in age at occurrence not significant.

indicating that animals of both breeds became afflicted with lumpy jaw at about the same ages.

The records were grouped according to four geographical areas. The test for heterogeneity of the data from the separate breeds had a chi-square value of 5.00, and with three degrees of freedom, this probability value of P = 0.2 to 0.1 indicated no heterogeniety. Therefore, the data were combined; the resulting chi-square value of 1.60, with three degrees of freedom, gave a probability of P = 0.7 to 0.6 and indicated that the cases of lumpy jaw reported were distributed in the four areas proportionately to the numbers of cows. This is summarized in Table 7. Data were analysed to see if the frequencies of lumpy jaw were the same in different parts of Ohio.

TABLE 7.—DISTRIBUTION OF LUMPY JAW CASES IN DIFFERENT GEOGRAPHICAL AREAS OF OHIO.

Area	Guernseys*		Holsteins*		Combined*	
	Lumpy Jaw	Not Affected	Lumpy Jaw	Not Affected	Lumpy Jaw	Not Affected
Northeast	10	1,559	15	12,119	25	13,678
Southeast	1	540	9	3,419	10	3,959
Southwest	6	1,352	3	3,389	9	4,741
Northwest	3	1,238	6	5,095	9	6,333
Total	20	4,689	33	24,022	53	28,711

* Differences in frequency among areas not significant within breeds or with breeds combined.

Analysis of the data was carried out to determine whether or not size of herd was a factor in incidence of lumpy jaw. As shown in Table 8, although no heterogeneity existed between the breeds in distribution of herds of various sizes in the four geographic regions of the state, when all of the data were combined, a pronounced and significant breed difference was seen. More Holstein herds were observed in the larger herd size groups and fewer in the small groups. Mean herd sizes of the two samples were 34.21 (standard deviation of 20.47) and 29.28 (standard deviation of 16.99) for the Holstein and Guernsey breeds respectively. The differences between these means and the variance associated with them were significant. However, as indicated in Table 9, this difference in mean herd size was not an important factor in causing the three-fold breed difference in incidence of lumpy jaw. It can be seen in both breeds that heterogeneity existed in the number of herds of various sizes from which lumpy jaw cases were reported. No significant breed difference was apparent in the proportion of lumpy jaw cases reported from herds differing in size.

TABLE 8.—DISTRIBUTION OF GUERNSEY AND HOLSTEIN HERDS OF VARIOUS SIZES AMONG GEOGRAPHICAL AREAS OF OHIO.

Area	Number of Cows in Herd					
	1–19	20–29	30–39	40–49	Over 50	Total
			Guernsey**			
Northeast*	10	15	10	7	6	48
Southeast	7	9	2	1	3	22
Southwest	12	11	10	3	7	43
Northwest	17	15	11	2	3	48
Total	46	50	33	13	19	161
Percent	28.6	31.0	20.5	8.1	11.8	100
			Holstein**			
Northeast*	57	76	97	47	59	336
Southeast	22	39	32	7	11	111
Southwest	20	26	21	15	17	99
Northwest	36	47	34	19	21	157
Total	135	188	184	88	108	703
Percent	19.2	26.7	26.2	12.5	15.4	100
Total	181	238	217	101	127	864
Percent	20.9	27.5	25.1	11.7	14.7	100

* Within-breed differences in herd size among areas not significant.
** Between-breed differences in herd size significant ($P < .025$).

Discussion of Survey.—Although data obtained by survey are frequently less than ideal, necessary requirements of a valid survey were met. Equivalent samples of the two breeds were obtained, as the proportion of replies from the two groups of breeders was similar. There was similarity of incidence of tailless and blind animals, and a like proportion of the Guernsey and Holstein breeders signed their replies. Differences in size of herds and unequal distribution of breeds in the four parts of the state were real, and agree with DHIA membership in the state. For estimates to be valid, it must be assumed that herds of the two breeds were managed similarly. The survey supplied no reports on this point. It would seem doubtful that any slight differences in this respect would be reflected in the large difference in number of lumpy jaw cases that were reported. An even larger breed difference was noted in the samples of bulls, many of which were reported by A.I. associations where animals of the two breeds are part of the same unit and managed even more similarly than were the two large samples of females.

TABLE 9.—HERD SIZES FROM WHICH CASES OF LUMPY JAW WERE REPORTED.

Size	Guernsey*		Holstein*		Combined	
	Cases	No Cases	Cases	No Cases	Cases	No Cases
			Number of Herds			
0-19	1**	45	1**	134	2	179
20-29	4	46	8	180	12	226
30-39	4	29	12	172	16	201
40-49	2	11	1	87	3	98
Over 50	6	13	8	100	14	113
Total	17	144	30	673	47	817

* Between breed differences in frequency of cases in herds of different sizes not significant.

** Differences in number of cases in herds of different sizes significant for each breed, and for breeds combined ($P < 0.01$, $P < 0.025$, and $P < 0.005$, respectively).

Selected Case Histories Within Herds

Attention was called in 1952 to the occurrence of a daughter and dam pair that had contracted lumpy jaw (V, B, and C, Figure 3). The owner examined the herd records and found an additional case, a paternal sister (VI, C) to the dam. Other cases were reported in the following months, several of which were by the same sire (VIII, E) as these two sisters. Another case (VI, E) was a maternal sister to the sire of these affected cows. A list of all 81 daughters by the sire was obtained through the courtesy of the breed association together with their 29 last recorded owners located in three states. These owners were queried during October 1955 and again in March 1962 to find out whether each named daughter was still in the herd and whether she was normal in all respects. If she was not, the owner was asked to state why she was removed from the herd. Lumpy jaw was not mentioned in these inquiries, although it was discussed with the original correspondent.

Responses were received from 20 herd owners of 76 daughters, 52 of which were no longer in the herd. Five owners accounting for five cows did not respond. From the responses, 15 cases of lumpy jaw or wooden tongue were disclosed. Most of these cases were diagnosed by one or more local veterinarians. Seven cases (C) were by the sire in question. Two of these were from cows sired by his maternal brother (VI, VII, C). The survey also located cases of lumpy jaw in two granddaughters of the first bull, both from his daughters. (See Figure 3.) Seven cases closely related in the ancestry were added later.

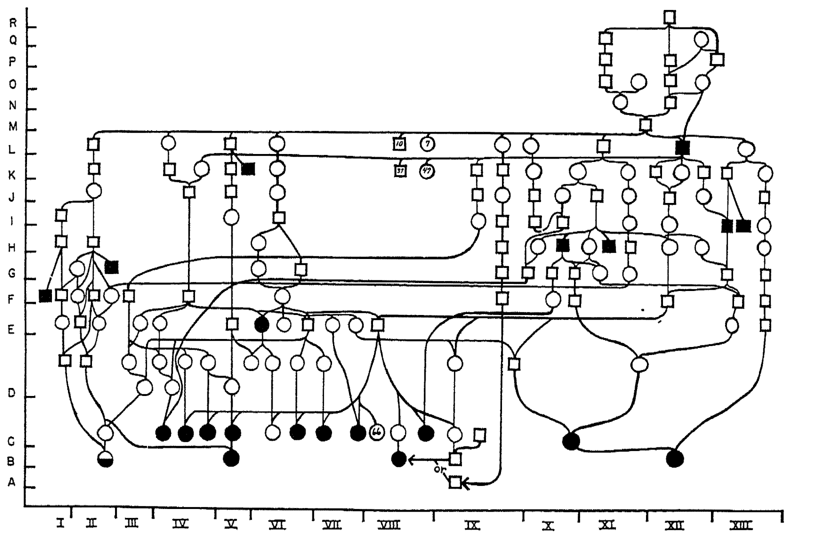

Figure 3.—Lumpy jaw cases among Guernsey cattle of known relationship. Cases of lumpy jaw trace on both sides to the sire of an afflicted son.

Four of the herds were visited in the company of the original correspondent during June 1954. Herd owners were interrogated regarding their breeding programs and herd management. The breeding programs varied considerably, although cattle were exchanged through sales among the various herds. There was no overriding emphasis on inbreeding in any herd. The management was good but not necessarily uniform. It was practical from a farmer-breeder's standpoint.

The owner of a large registered Guernsey herd in another state reported a cow, daughter, and granddaughter affected with the soft-tissue type of lumpy jaw. The lesion of the youngest cow was near the eye socket. The owner suspected that heredity was involved with this condition because of its occurrence in this one female line.

In an institutional Guernsey herd, a bull was slaughtered for lumpy jaw. Several daughters contracted the disease in subsequent years. These were the only cases of lumpy jaw which the manager recalled in the herd. The two grandsires of this bull had four affected grandsons in other herds.

DISCUSSION

Both types of lumpy jaw, actinomycosis and actinobacillosis, were reported in several breeds of cattle. The soft-tissue type of infection is often treated with iodine compounds, but the bone-type appears more resistant to treatment. Bone-type cases sometimes respond to streptomycin.

Frequencies among beef and dairy bulls did not differ significantly, but data on the beef breeds were very limited. The frequency among Guernsey bulls was seven times that of the other breeds. Among cows surveyed in Ohio, the Guernsey frequency was three times that of Holsteins. To the extent that breed differences may be called genetic, therefore, a heritable susceptibility to lumpy jaw was indicated.

Several attempts were made to determine whether genetic differences in lack of resistance existed within the breeds. Numerous instances of lumpy jaw were observed among closely related individuals. For example, four generations of males contracted the condition. Three generations of females also were affected. Many sires had sons and/or grandsons with the condition, as well as other relatives. One sire appeared in the pedigree of 12 cases within five generations, and 33 cases were in four generations descended from his full sister. This pair and seven other males appeared in the pedigrees of 145 cases within five generations.

Attempts to evaluate these relationships quantitatively were not markedly successful, perhaps because of the limited numbers of cases. The frequency of lumpy jaw cases among the seven closest male ancestors of affected Guernsey males in artificial insemination was higher than among ancestors of a control group (10.0 percent versus 6.7 percent), but this difference was associated with a probability level of only about 0.15.

When dealing with a pathogenic condition of known causative agents, incontestable proof of genetic influence on occurrence frequently has been difficult to obtain. The numbers of cases generally have been small, and records difficult to accumulate. In this investigation, a population of over 45,000 individuals was studied, with slightly more than 400 cases. Furthermore, it must be assumed that resistant animals would contract the condition if exposure was great enough, and highly susceptible individuals would not under reverse conditions. These factors tend to mask possible genetic effects.

An additional problem is that of environmental correlation. Related individuals tend to live in the same environment (i.e., farm), and frequencies of any condition, genetically influenced or not, tend to occur more often in some groups of related animals than others. Males, however, are usually housed separately on farms and do not have close contact with other males or females. This is especially true in artificial breeding studs.

In this investigation, the related lumpy jaw cases were frequently on different farms or studs, many times being in other states. Also, the time interval between occurrences generally was long. With an average generation length in cattle of about five years, a four-generation study would probably involve over 20 years. This would decrease or eliminate effects of a common environment even if all affected animals had been on the same farm.

SUMMARY

Lumpy jaw accounted for death or disposal of 2.13 percent of 16,249 males of the various beef and dairy breeds. A distinction into cases of soft-tissue or bone-type was not reported in some instances. In a survey of 29,182 cows, 0.2 percent were reported with the condition.

Frequencies among dairy bulls averaged 2.15 percent and among beef bulls, 1.31 percent. These differences were not significant, there being only 382 completed records of beef bulls. Among dairy bulls, the frequency was seven times as great among Guernseys as in the other breeds. The other breeds did not differ significantly from each other. Among females, the frequency of infection was three times higher in Guernseys than in Holsteins.

There were many cases of related individuals with the condition, frequently at different farms or studs, and with a number of years between time of contraction. The evidence of genetic differences in susceptibility was convincing. It was not possible to quantify the genetic portion of the variability, which would doubtless necessitate designed experimentation.

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