FREQUENCY OF AND MODE OF INHERITANCE OF WRY TAIL, SCREW TAIL AND TWISTED FACE IN A HERD OF JERSEY CATTLE

by

MORRIS BRILEY EWING

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INTRODUCTION

Defects in body conformation are of concern to breeders interested in breeding animals to conform closely to breed association standards. If such defects are hereditary, they can be successfully controlled or reduced in frequency by proper breeding methods. The propriety of such methods depends on the mode of inheritance of these defects. The purpose of this study was to determine the mode of inheritance of three such body conformation defects - wry tail, screw tail, and twisted face in Jersey cattle. In addition, further study concerning the relationship of these defects, their apparent frequencies, and the occurrence of variations in their frequencies among animals of different ages was made. Study of such defects is of utilitarian value to breeders because it affords information upon which decisions in the selection of breeding stock and of breeding methods may be based.

Many defects in body conformation are known to occur in cattle. However, only nine have been listed on the Purebred Dairy Cattle Scorecard (18) as being of sufficient importance to justify slight discrimination to disqualification of animals possessing such defects in the show ring. These defects are: blindness in one or both eyes, wry face, parrot jaw, winged shoulders, capped hip, wry or abnormal tail settings, defects in feet and legs resulting in lameness, lack of size, and defects of the udder.

In addition to these show ring standards which are common to all breeds of dairy cattle in the United States, similar standards exist for the type classification programs of each breed of dairy cattle. In the Jersey breed, the breed from which the data in this study were taken, two herd classification pamphlets published shortly after 1939 and 1941, respectively, contained statements that animals with distinct wry tail settings, wry faces, or with markedly cross eyes were to be classified one place lower than animals of equal merit not possessing these defects. A more recent revision of this Jersey Herd Classification pamphlet (17) in 1949 contained a statement that any animal possessing wry tail, screw tail, or other similar defects was not to be penalized for these defects in the classification score. However, such defects were to be brought to the attention of the American Jersey Cattle Club for their records. This change in policy was caused by the fact that only animals that exhibited a recessive defect would be subject to discrimination whereas the normal appearing but similarly tainted carrier animals would not be stigmatized.

REVIEW OF LITERATURE

Tail Abnormalities in Cattle

Since the first report of wry tail was published by Atkeson and Warren (3) in 1935, studies related to the mode of inheritance of this and similar traits in cattle have been infrequent. Therefore, reference has been made to studies with other animals such as mice, which have been more extensively investigated.

Anatomical defects may be complex in their mode of inheritance and variable in expression. The development of the bovine embryo has not been sufficiently described to permit determination of possible embryological causes of anatomical malformations. However, it has been shown by Winters, et al. (19) that in the development of the bovine embryo, ossification of the coccygeal vertebrae is under way at 90 days.

According to Grueneberg (9), processes in the formation of the mammalian skeleton, which are extremely complex, may be disturbed by gene action. Configuration also may be influenced by other systems such as the muscles. According to Sisson and Grossman (15) the sacrum of the ox consists of five fused segments and the spinous processes on the dorsal surface are fused to form the median sacral crest. A lateral crest is formed by fusion of the articular processes. They state that the number of coccygeal vertebrae in the ox varies from 16 to 21. Five muscles are described by McLeod (12) as controlling the movement of the tail. These are: M. intertransversalis caudae, M. dorsal sacrococcygeus, M. sacrococcygeus lateralis, M. sacrococcygeus ventralis, and the M. coccygeus. McLeod (12) states that the actions of these muscles are complex if considered separately. However, considered in groups, the ventral muscles depress the tail and the intertransverse muscles are lateral flexors of the tail. All of the muscles on one side of the tail are lateral flexors and the opposite group are extensors. The

M. coccygeus is thin and flat. Its origin is near the ischiatic spine and insertion is the transverse process of the second and third coccygeal vertebrae. In the horse, Sisson and Grossman (15) state that the consolidation of the sacrum is usually complete at three years. They also state that in old horses the first coccygeal vertebra is often fused with the sacrum.

Wry Tail

The first technical study of wry tail in dairy cattle was reported by Atkeson and Warren (3). From a study of three herds of Jersey cattle they concluded that this defect was quite prevalent throughout the Jersey breed and possibly also in other breeds of dairy cattle. Atkeson, et al. (2) in 1944 reported that wry tail was found in Brown Swiss, Guernsey, Holstein and Ayrshire cattle. Gilmore and Sellers did not find any evidence of wry tail in 107 animals in three beef breeds - Shorthorns, Herefords and Angus. However, they did report one wry tail animal among 30 observed in the Red Polled breed. Even though wry tail has not been reported in these three beef breeds, it seems unreasonable to conclude that wry tail does not exist since such small numbers were observed. The frequency of occurrence of wry tail in these various breeds as found by these authors has been summarized in Table 1.

Table 1. Frequency of wry tail observed in several breeds of cattle.

Investigators	Date	Breed	Number of herds	Number animals observed	Number wry tail	Percent wry tail	Wry tail gene frequency
Atkeson and Warren	1935	Jersey	3	--	9	--	--
Atkeson, Eldridge and Ibsen	1944	Jersey	10	350	117	33.5	58
		B. Swiss	34	505	101	20.0	44.7
		Guernsey	1	17	4	23.5	--
		Holstein	5	142	7	4.9	--
Gilmore and Sellers	1948	Shorthorn	--	51	0	0.00	--
		Hereford	--	17	0	0.00	--
		Angus	--	39	0	0.00	--
		Red Poll	--	30	1	0.03	--

Because of the limited numbers observed and the selection of herds that were known to be affected, the incidence of wry tail, as listed in this table, could not be expected to approximate the frequency that actually prevails in any of these breeds, except possibly in the Brown Swiss breed.

The gene frequency estimate for the Brown Swiss breed obtained by Atkeson, et al. (2) was derived from study of animals in randomly selected herds, whereas that for the Jersey breed was derived from study of animals in herds known to include wry tail animals. Although no estimate of the frequency of wry tail in Ayrshires was obtained by Atkeson, et al.(2), they believed it to be low. Atkeson (1) stated that wry tail also existed in the Milking Shorthorn breed.

Atkeson and Warren (3) concluded that the wry tail character was definitely heritable. They believed it to be inherited as a simple recessive. Atkeson, et al. (2) studied the mode of inheritance of wry tail in three Jersey herds that had 73 affected animals. They concluded that wry tail was inherited as a simple recessive. Roemmele (14) observed a wry tail-like defect in a Brown Allgäu Spotted Mountain Cow and her two progeny. He assumed that the character was inherited in a dominant manner. Roemmele reported studies made by Stoss regarding the anatomy of this apparent "wry tail condition." Roemmele quoted Stoss as stating that the sacrum was normal except that the left halves of the third, fourth and fifth sacral vertebrae were more developed, and located slightly more posteriorly than the right half. Although the tail set of this animal was probably to the right, Atkeson, et al. (2) indicated in their studies that the set of the tail was non-genetic in character. Stoss also found the tail vertebrae to be irregular. The third vertebra was affected to the extent that it did not resemble a normal tail vertebra. The entire vertebra was rotated on its axis about 180°. The intervertebral disc often enclosed the entire vertebra, causing it to deviate from a straight line.

Gilmore and Sellers (7) made anatomical and radiographical observations on a wry tail cow. They found that the wry tail condition was due to insufficient bone growth in the fusion area between the third and fourth sacral segements. In addition, forty-two percent of the total declination occurred within the body of the fourth sacral segment. In this cow, they found that the declination was 12°, and involved the sacrum rather than the tail head. Gilmore (6) reported that no cases of wry tail had ever been reported in calves at birth. Atkeson and Warren (3) published pictures of young calves with wry tails.

Screw Tail (Kinky-Tail)

Atkeson (1) stated that the screw tail defect had also been observed in the Holstein and Brown Swiss breeds and possibly others. Emmel and Knapp (5) reported on a kinky-tail condition in four Red Polled cattle. All four kinky-tailed cattle possessed motility of the kink at birth. However, after a four to six week period, fusion was complete. The authors concluded that this defect was due to the action of a single gene. Knapp _et al_. (11), having studied the daughters of a screw tail (kinky-tail) Red Polled bull, concluded that the character was inherited as a simple recessive. They reached this decision after observing three screw tail and three normal progeny which resulted from mating this affected bull with six known carrier cows. However, they mentioned that other factors may be involved which regulate the number of vertebrae affected. Knapp _et al_.(11) believed two or more abnormalities might occur together. They mentioned that a screw tail bull also sired some cryptorchid as well as screw tailed progeny. However, they found no relationship between the incidence of the latter character and the screw tail character.

Twisted Face

Although the twisted or wry face condition has been recognized for some time by breed associations and breeders, little has been published on this character in cattle. In addition to the Jersey breed, Atkeson (1) observed the twisted face defect in several other breeds. These breeds were: Holstein, Guernsey, Brown Swiss and Ayrshire. Hancock (10) observed one case of twisted face in monozygotic Jersey twins. He stated that one of these twins although born with a straight face, developed a definite twisted face when more mature. The co-twin remained normal.

Similar Defects in Other Species

Similar defects in other species have been studied in more detail than in cattle. In swine, Nordby (13) found that kinky or screw tail was inherited as a simple recessive. However, he did not always obtain expected ratios in backcrosses. He noted that vertebrae fused end-to-end and suggested that the presence of inhibitory influences may interfere with the normal ratio. Also, he found a more frequent occurrence of this anomaly in closely inbred herds. In mice, Grueneberg (9) reported that the screw tail condition occurs as a simple recessive. Contrary to this, however, he cited two similar tail anomalies, kinky tail and fused tail as being dominant. However, he noted that a deficiency of screw tail mice from carrier matings might be due to a high incidence of pre-natal mortality and he added that screw tail mice are often stillborn. Grueneberg also stated that, "the teeth and jaws of screw tail mice are very abnormal". These abnormalities in both upper and lower incisors in mice increased in severity with age. He reported that first litters had a higher incidence of screw tail abnormalities. Burns (4) reported on the mode of inheritance of several anomalies in the dog. He stated that kinky tail observed in Bulldogs has been reported to be dominant to straight tail. He cited Stockard <u>et al</u>. as stating that a pair of unlinked genes determine whether the tail would be long (dominant) or short. Whitney is also cited by Burns (4) as stating that this explanation is too simple. Whitney found no simple mode of inheritance of tail carriage or length in crosses between breeds. The F_1 tails were usually intermediate to those of parent types. He suggested multiple factors were probably involved. Koch was quoted by Burns (4) as saying that a number of congenital conditions such as corkscrew tail and others are due to hereditary abnormality of the anterior pituitary rather than a series of linked genes.

Keeler studied the twisted nose condition in mice in 1929 and his results were quoted by Grueneberg (9). This condition was found in three closely related mice. The twisting of the nose was due to shortening of the nasal bone on one side. Grueneberg states " - the relationship of these animals is compatible with the assumption that the twisting was conditioned by a dominant gene with normal overlapping."

EXPERIMENTAL PROCEDURE

The data used in this study were a part of a large body of data obtained on a single large herd of Jersey cattle by F. W. Atkeson and Franklin E. Eldridge, during the period from July 1st to July 5th, 1950. Data were collected on seven characteristics in this herd. Three of these, wry tail, screw tail and twisted face, were selected for this study. Information for these three characteristics was obtained from 577 daughters of 86 sires. One sire's daughters, 24 heifers, were observed only for the wry tail character. Five herd sires were also observed. Two were normal for all three characters, two had wry tails, and one had both wry tail and twisted face. However, the sire with both defects had no progeny in this study. Unpublished work by Huston (8) indicates that no appreciable degree of inbreeding existed in this herd. The animals, with the exceptions previously noted, were classified for the characters as indicated in Table 2.

Table 2. Characters, classification system, and code symbols for wry tail, screw tail and twisted face defects.

Character	Classification	Code Symbol
Wry tail	1. Normal	N
	2. Wry Right	WR
	3. Wry Left	WL
Screw tail	1. Normal	N
	2. Screw tail	Scr
Twisted face	1. Normal	N
	2. Medium Right	TwF MR
	3. Medium Left	TwF ML
	4. Severe Right	TwF SR
	5. Severe Left	TwF SL

Wry tail was defined as the condition in which the base of the tail deviates laterally from the line of the vertebral column. Screw tail was defined as the bending, kinking, or twisting of the coccygeal vertebrae resulting in a distorted, shortened,and abnormal appearance. Twisted face was defined as a turning or bending of the face, or a combination of both, that distorts its normal symmetry.

Each of the three characters was subjected to a preliminary check to see if it were caused by the action of a simple dominant gene with complete penetrance. If this assumption were correct, two normal parents should produce nothing but normal offspring.

After the check for dominance, characters were checked to see if they were simple recessives. Although this could be done by pedigree analysis or with various sib methods, such methods were not used. The pedigree method was not used because all animals in the pedigrees had not been observed. The sib method was not used because of the small size of families. The method used was to examine progeny ratios of bulls classified by phenotype as affected, or as a carrier on the basis of progeny test. Since the sires classified as carriers solely on the basis of progeny test had a large number of progeny it seemed unnecessary to adjust the progeny ratios for the _propositi_.

Mates of the bulls were classified as affected, normal or unobserved. Affected mates were assumed to be the recessive homozygotes for the observed defect.

Since normal mates could not be identified phenotypically as either homozygous normal or carrier animals, several assumptions had to be made in order to test the ratios observed among their progeny.

For the wry tail character, the observed normal mates were assumed, either a, to be all carriers, or b, to possess the gene in a frequency estimated for normal animals from the earlier work of Atkeson, <u>et al</u>. (2). The first assumption provided the maximum frequency of the recessive gene that can occur in normal animals. If the number of affected progeny from observed normal dams, all assumed to be carriers, and supposed carrier bulls is in excess of the number expected, the hypothesis of a simple recessive is easily rejected. The second assumption provided a more realistic estimate of the frequency of the recessive gene among the normal mates. It is not, however, a positive test inasmuch as the frequency could through chance sampling be much higher or lower. The unobserved mates, referred to as "unknowns" hereafter, were assumed either a. to be all affected or b. to be all carriers, or c. to possess the gene frequency estimated by Atkeson, <u>et al</u>. (2), or d. to possess the gene frequency estimated from these data. The first assumption provided the maximum frequency of the recessive gene (1.00) that could occur in unobserved animals. If the number of affected progeny from unknown dams, all assumed to be affected, and carrier bulls is in excess of the number expected, the hypothesis of a simple recessive is easily rejected. The second, third and fourth assumptions provided more realistic estimates of the frequency of the recessive gene among unknown mates. These estimates for each assumption were, respectively, 0.50, 0.57, and 0.67. None of these was a positive test inasmuch as the frequency could through chance sampling be much higher or lower.

For the screw tail and twisted face defects the affected mates were assumed to be the recessive homozygotes for the observed defect. The normal mates were assumed either a. to be all carriers, or b. to possess the gene frequency estimated from these data. The unknowns were assumed either a. to be all carriers, or b. to possess the gene frequency estimated in these data. These assumptions were made for the reason previously stated.

The gene frequency estimates obtained from the data of this study were used with complete awareness of the general undesirability of such use. The undesirability of such usage stems from the fact that the progeny ratios are tested against a hypothesis based on an estimate obtained from these same progeny. However, it seemed desirable to determine whether the progeny ratios were in accord with even this normally uncritical test.

All ratios obtained in studying each of these three characters were tested by chi-square according to the methods outlined by Snedecor (16).

RESULTS

Five hundred and seventy-seven daughters of 86 bulls were classified for all three characters. The distribution of these daughters by sires is presented in Table 3. Analyses of data on each character, on the association of these characters with one another, and on the association of each character with age, are presented hereafter.

Table 3. Distribution of daughters by sires.

Number of daughters per sire	Number of sires	Total number of daughters	Average number of daughters per sire
30 or more	6	316	52.7
10 - 29	9	123	13.7
5 - 9	8	58	7.2
3	6	18	3.0
2	5	10	2.0
1	52	52	1.0
Total and av.	86	577	6.7

Wry Tail

<u>Frequency and Nature of Occurrence</u>. The frequency of the wry tail defect among the cows observed in this herd is shown in Table 4. The frequency of wry tail in this herd was much greater than that reported in any previous study.

Table 4. Frequency and percent of cows affected with wry tail.

	Cows observed	Percent
Affected	263	45.6
Normal	314	54.4
Total	577	100.0

The frequency of occurrence of wry left and wry right tail was studied by Atkeson et al. (2). They found wry tail to the left to occur as frequently as wry tail to the right. The frequency of wry left and wry right tail in these data is shown in Table 5. Wry right and wry left tail did not occur with equal frequency; wry right tail occurred more frequently than wry left tail.

Table 5. Frequency of wry left and wry right tails.

	Wry left	Wry right
Observed	100	163
Expected	131.5	131.5
$X^2 = 15.10^{**}$ ($P < 0.005$) (1 d.f.)		

The frequency of wry tail progeny from wry tail dams and normal dams was compared in Table 6. There was no significant difference in the number of affected progeny in the two groups. These results are suggestive of a trait of low heritability.

Table 6. Frequency of wry tail progeny from normal dams and from wry tail dams.

	Normal progeny	Wry tail progeny	Total
Normal dams	44	27	71
Wry tail dams	33	34	67
$X^2 = 2.269$ n.s. (1 d.f.)			

Analyses were made to determine whether wry right or wry left tails occurred more often among progeny from dams which had wry right or wry left tails. In Table 7, the progeny from wry tail cows are listed according to whether they were from dams with wry left or wry right tails.

Table 7. Frequency of occurrence of wry left and wry right tails among progeny of wry left and wry right dams.

Dams	Normal prog.	Wry left prog.	Wry right prog.	Total prog.
Wry left	14	3	4	21
Wry right	19	9	18	46
Totals	33	12	22	67

$X^2 = 3.886$ n.s.
(2 d.f.)

There was no significant difference in the occurrence of either wry left or wry right progeny from wry left or wry right cows. Also, when comparing the occurrence of wry right and wry left progeny from normal dams no significant difference was found, as is shown in Table 8.

Table 8. Frequency of wry left and wry right tails observed in progeny from normal dams.

Normal dams	Wry left prog.	Wry right prog.	Total prog.
Observed	10	17	27
Expected	13.5	13.5	27

$X^2 = 1.80$ n.s.
(1 d.f.)

The number of wry tail and normal tail progeny sired by each bull was compiled. The bulls were then grouped according to both the total number of observed progeny and the occurrence of a wry tail animal among these progeny. The distribution of bulls according to these classifications is presented in Table 9.

Table 9. Distribution of sires according to number of wry tail animals among progeny.

Sire classification	Number of sires	Number of wry tail progeny by these sires	Number of normal progeny by these sires	Total number observed
Sires with three or more total progeny and at least one wry tail progeny.	29	231	284	515
Sires having only one or two progeny and at least one wry tail progeny.	30	32	1	33
Sires having three or more progeny and no wry tail progeny.	0	0	0	0
Sires having only one or two progeny and no wry tail progeny.	27	0	29	29
Total	86	263	314	577

Fifty-nine of these 86 sires sired wry tail progeny. Every sire with three or more observed progeny had at least one or more observed wry tail progeny. Only two sires had as many as two observed progeny without having at least one wry tail offspring.

Genetic Tests. Test for Dominance. Sire B, (Table 11) observed to be normal for wry tail, when mated to normal cows, produced wry-tailed offspring. Therefore, a simple dominant mode of inheritance can be excluded.

Tests for Recessive. The progeny of two wry tail sires, one wry left and one wry right, were examined. Both sires, although wry tail, sired normal progeny. Sire J, when mated with four wry tail cows, produced four normal daughters. The number and kind of progeny of these two wry tail bulls and affected, normal, or unknown cows are shown in Table 10.

Table 10. Progeny of wry tail bulls and affected, normal, or unknown cows.

Sire	Total progeny	Wry tail prog.		Total wry tail	Total normal	Prog. from wry mates		Prog. from normal mates		Prog. from unknown mates	
		WR	WL			Wry	normal	Wry	normal	Wry	normal
I (WR)	11	4	1	5	6	2	0	1	0	2	6
J (WL)	15	4	1	5	10	0	4	2	2	3	4

If the data are accepted as authentic, the normal progeny of the four critical wry tail X wry tail matings proved that wry tail is not a simple recessive trait. Inasmuch as these critical matings all rest on the accurate classification of a single bull, it was deemed desirable to examine most of the remaining data to determine whether a simple recessive hypothesis was satisfactory.

Eight bulls which sired a total of 322 observed offspring were classified as carriers because they had sired both wry tail and normal offspring from wry tail cows. The ratio of wry tail to normal animals found among the progeny of each of the eight bulls was tested against the hypotheses outlined in the procedure. The results of these tests of hypotheses are presented in Table 11.

As can be seen in this table, the ratio of wry to normal progeny from the carrier bulls and wry tail cows did not deviate significantly from expectation. However, an excessive number of wry tail progeny from carrier bulls and observed normal mates was observed even when observed normal mates were all considered to be "carrier" animals. This excess was also observed when the normal mates were considered to possess the gene frequency estimated by Atkeson _et al_. (2).

The number of wry tail progeny from carrier bulls and unknown mates was in excess of the number expected under three of the four hypotheses concerning the genetic makeup of the mates. The observed progeny ratio of 94 wry tailed to 119 normal animals could have resulted under the unlikely supposition that all unknown cows were wry tail cows.

The progeny of one bull, all heifers, were excluded from the previous analyses because they did not constitute all or a random sample of all of the heifers in the herd. These heifers

Table 11. Observed wry tail and normal progeny of eight carrier sires from matings with affected, normal, and unknown cows.

Sire	Total progeny	Wry tail progeny	Progeny from wry mates: Wry	Progeny from wry mates: Norm.	X^2_1	Progeny from normal mates: Wry	Progeny from normal mates: Norm.	X^2_2	X^2_3	Progeny from unkn. mates: Wry	Progeny from unkn. mates: Norm.	X^2_4	X^2_5	X^2_6	X^2_7
A	91	42	6	3	1.000	2	6	0.000	0.257	34	40	0.486	17.310*	10.243*	6.166*
B	67	26	8	14	1.636	5	5	3.333	7.717*	13	22	2.314	2.677	1.260	0.126
C	49	19	2	3	0.200	4	6	1.200	3.749*	13	21	1.882	3 .176	1.369	0.538
D	42	15	3	5	0.500	3	5	0.666	2.217	9	17	2.460	1.281	0.422	0.000
E	31	14	3	3	0.000	1	6	1.213	0.040	10	8	0.222	8.963*	6.230*	4.001*
F	16	9	0	2	2.000	2	0	6.000*	11.333*	7	5	0.232	7.111*	4.941*	3.375*
G	14	9	3	1	1.000	0	2	0.383	0.829	6	2	2.000	10.666*	8.353*	4.800*
H	12	7	1	1	0.000	2	0	6.000*	11.333*	4	4	0.000	2.666	1.763	0.533
Totals	322	141	26	32		19	30			94	119				
X^2 (7 d.f.) (Total)					6.336			18.795*	37.475*			9.596	53.853*	34.581*	19.539*
"Goodness of Fit" − X^2 (1 d.f.)					0.620			5.047*	15.692*			2.460	43.622*	26.195*	13.142*
= heterogeneity X^2 (6 d.f.)					5.716			13.748*	21.783*			7.136	15.231*	8.386	6.397

Mates assumed:

1 = to be all recessive homozygotes
2 = to be all carriers
3 = to possess Atkeson _et al._ (2) estimated frequency of the gene for normals
4 = to be all affected
5 = to be all carriers
6 = to possess Atkeson _et al._ (2) estimated frequency of the gene for wry tail
7 = to possess gene frequency for this study (0.67).

were examined only for the wry tail character. Information relative to these heifers is presented in Table 12.

Table 12. Frequency of wry tail among daughters of a bull, observed to be normal, and his wry tail, normal, and unknown mates.

Sire	Total progeny	Wry tail: WR	Wry tail: WL	Prog. from wry mates: Wry	Prog. from wry mates: Normal	Prog. from normal mates: Wry	Prog. from normal mates: Normal	Prog. from unknown mates: Wry	Prog. from unknown mates: Normal
X	24	5	3	3	6	0	8	5	2

The number of wry tail progeny of this bull and his mates was in accord with that expected under a simple recessive hypothesis.

The data presented here did not support the hypothesis that all wry tails were produced by a completely penetrant recessive gene in the homozygous state, except under extremely improbable conditions. Therefore, it seemed desirable to search for an alternative genetic hypothesis.

Tests for Alternative Hypotheses. Many alternative hypotheses exist that might have been tested. Several were examined. These were: a) that wry tail was produced by the action of two pairs of independent genes; b) that wry tail was produced by the action of a single pair of genes, with one of the alleles being incompletely penetrant; and c) that some wry tails may result from environmental causes.

With the exception of duplicate recessive epistasis, all two-pair hypotheses including incomplete dominance in both pairs, incomplete dominance in one pair, dominance in both pairs, and any one of the following forms of epistasis: recessive, dominant and recessive, duplicate dominant, and incompletely duplicate epistasis were readily excluded either because only two phenotypes exist or because neither normal animals nor wry tail animals bred true. No attempt was made to determine whether the duplicate recessive epistasis theory would satisfactorily account for the occurrence of wry tail in this herd.

Two alternative explanations based on the assumption of incomplete penetrance were examined. These were that wry tail was caused either by the actions of an incompletely penetrant dominant gene or by the action of an incompletely penetrant recessive gene in the homozygous state. The data as assembled for the previous tests were inadequate to test these alternatives. However, the incompletely penetrant dominant gene theory seemed to be more desirable as it required a lower frequency of the undesired wry tail gene than did the alternative theory. Inasmuch as the wry tail trait is an undesirable trait, it should have been subject to selection for many generations. Hence, the frequency of the gene causing wry tail should have been continually reduced. The assumption of an incompletely penetrant recessive gene required a gene frequency in excess of 0.67, (the frequency estimated in this study) whereas the alternative hypothesis only required a frequency in the range from 0.67 to 0.30.

Screw Tail

Frequency and Nature of Occurrence. The prevalence of screw tail in this herd is shown in Table 13. The frequency of occurrence of this defect was lower than that of the wry tail defect.

Table 13. Frequency and percent of cows affected with screw tail.

	Cows observed	Percent
Affected	107	18.5
Normal	470	81.5
Totals	577	100.0

The frequency of the recessive gene supposed to cause screw tail was calculated to be 0.43. The frequency of the gene for normal tail was therefore 0.57. Screw tail cows did not produce more screw tail progeny than did normal cows. This indicates that this character is not highly heritable. These results are shown in Table 14.

Genetic Tests. Test for Dominance. Sires B and I, both observed to be normal for screw tail, were mated to normal cows and produced screw tail progeny. Therefore, the simple dominant hypothesis can be ruled out.

Table 14. Occurrence of screw tail progeny among progeny from normal dams and from screw tail dams.

	Normal progeny	Screw tail progeny	Total progeny
Normal dams	84	18	102
Screwtail dams	29	7	36
Totals	113	25	138
$X^2 = 0.000$ (1 d.f.)			

Test for Recessive. No test by examination of critical matings was possible as no sires were observed to have the screw tail defect.

Nine bulls which sired a total of 354 observed offspring were classified as carriers because they had sired both screw tail and normal offspring from screw tail cows. The ratio of screw tail to normal animals found among the progeny of each of the nine sires was tested against the hypotheses outlined in the procedure. The results of these tests are presented in Table 15.

The number of screw tail progeny among the progeny of supposed carrier sires and screw tail mates was significantly smaller than expected even after adjustment for propositi. However, the number of screw tail progeny among the progeny of supposed carrier sires and cows observed to be normal was not significantly different from expectation for that hypothesis.

Table 15. Observed screw tail and normal progeny of nine carrier sires from matings with affected, normal, and unknown cows.

Sire	Total progeny	Screw tail progeny	Progeny from screw tail mates		X_1^2	Progeny from normal mates		X_2^2	Progeny from unknown mates		X_3^2	X_4^2	X_5^2
			S-tail	Normal		S-tail	Normal		S-tail	Normal			
A	91	17	1	5	2.666	1	10	1.485	15	59	26.162	0.833	0.020
B	67	9	1	6	3.572	6	15	0.143	2	37	31.400	8.291	5.935
C	49	10	1	3	1.000	3	8	0.030	6	28	14.236	0.980	0.179
D	42	4	0	2	2.000	2	12	0.857	2	24	18.616	4.153	2.701
E	31	1	0	3	3.000	0	10	3.333	1	17	14.222	3.629	2.615
I	11	1	1	1	0.000	0	1	0.333	0	8	8.000	2.667	2.159
J	15	2	0	2	2.000	1	4	0.067	1	7	4.500	1.167	0.366
K	36	11	0	2	2.000	1	1	0.667	10	22	4.500	0.667	1.189
L	12	1	0	1	1.000	1	2	0.111	0	8	8.000	2.667	2.159
Total	354	56	4	25		15	63		37	210			
X^2 (8 d.f.) (Total)					17.238*			7.026			129.636*	25.104*	17.323*
"Goodness of Fit" X^2 (1 d.f.)					15.206*			1.384			121.170*	13.273*	6.170*
Heterogeneity X^2 (7 d.f.)					2.032			5.642			8.466	11.831	11.153

Mates assumed:

1 = to be all recessive homozygotes
2 = to be all carriers
3 = to be all affected
4 = to be all carriers
5 = to possess gene frequency for this study (0.43)

The number of screw tail progeny among the progeny of supposed carrier sires and unknown mates was significantly smaller than expected from any one of three hypotheses tested. The results appear to be sufficient to rule out a simple recessive hypothesis but the mode of inheritance was not determined.

Twisted Face

Frequency and Nature of Occurrence. Twisted face was observed in 124 animals in this study. The frequency of the twisted face defect among cows in this herd is shown in Table 16.

Table 16. Frequency and percent of cows affected with twisted face.

	Cows observed	Percent
Affected	124	21.5
Normal	453	78.5
Totals	577	100.0

As was the case with wry tail, twisting of the face occurred in two directions; to the left and to the right. The observed frequencies of twisted right and twisted left face are listed in Table 17. In contrast with relative frequency of wry left and wry right tail, 16 percent more faces were twisted to the left than to the right. This deviation from the assumption of equal frequency of occurrence of twisted right and twisted left face approached significance.

Table 17. Frequency of twisted left and right face in entire herd.

	Twisted left face	Twisted right face	Total
Observed	72	52	124
Expected	62	62	124

$X^2 = 3.224$, $0.10 > P > 0.05$
(1 d.f.) n.s.

The frequency of twisted face progeny from twisted face dams and normal dams was compared in Table 18. There was no significant difference in the number of affected progeny in the two groups. These results are suggestive of a trait of low heritability.

Table 18. Frequency of twisted face progeny from normal dams and from wry tail dams.

	Normal progeny	Twisted face progeny	Total
Normal dams	87	28	112
Twisted face dams	19	11	30

$X^2 = 1.962$ n.s.
(1 d.f.)

Analyses were made to determine whether twisted left or twisted right faces occurred more often among progeny of dams which had twisted left or twisted right faces. In Table 19, the progeny from twisted face cows are listed according to whether they were from twisted left or twisted right dams. No significant difference in the direction of twist of face was found among the progeny of cows with either twisted left or twisted right face.

Table 19. Frequency of normal, twisted left, and twisted right face progeny from twisted face dams.

Dams	Normal progeny	Twisted left face progeny	Twisted right face progeny	Total progeny
Twisted left face	11	3	2	16
Twisted right face	8	5	1	14
Totals	19	8	3	30

$X^2 = 1.107$ (2 d.f.) n.s.

However, when comparing the occurrence of twisted left and right face progeny from normal cows, the number of observed twisted left faces was significantly greater than right twisted faces. Based on a random mating population it was assumed that twisted left and right face progeny should occur with equal frequency from normal face dams. In Table 20, these frequencies are listed.

Table 20. Frequency of twisted left and right face progeny from normal dams.

Normal face dams	Twisted left face progeny	Twisted right face progeny	Total
Observed	19	6	25
Expected	12.5	12.5	25

$X^2 = 6.76^*$ $P < 0.010$
(1 d.f.)

Genetic Tests. Test for Dominance. Sires B and I, both observed to be normal for twisted face, when mated to normal face cows, produced twisted face progeny.

Test for Recessive. Since no affected bulls were observed it was not possible to observe a critical mating as a test for a recessive character.

For use in further testing of the simple recessive hypothesis, frequency of the twisted face gene was estimated from data in Table 16. Assuming equilibrium proportions, the frequency of the twisted face gene (tf) was 0.46 and the frequency of its allele (Tf), 0.54. The equilibrium proportions of normal (homozygous), normal (heterozygous), and affected animals were, respectively, 28.8 percent, 49.7 percent, and 21.5 percent. The dubiousness of these calculations has been pointed out previously.

Ten bulls which sired a total of 363 observed offspring were classified as carriers because they had sired normal face offspring from twisted face cows and twisted face offspring from other cows. The ratio of twisted face to normal face animals found among the progeny of each of the ten bulls was tested against the hypotheses outlined in the procedure. The results of these tests are presented in Table 21.

As can be seen in this table, the ratio of twisted face to normal progeny from carrier bulls and twisted face cows did not deviate significantly from expectation ($0.10 > P > .05$). If allowances are made for the propositi, the probability of the deviation from expectation lies between 0.75 and 0.50. None of the remaining evidence presented in this table is sufficient to invalidate the simple recessive hypothesis. It may be tentatively concluded that twisted face is a simple recessive trait.

Occurrence of More than One Defect in the Same Animal

Several comparisons have been made to determine if animals affected with one or two specified defect(s) were likely to also have a second, or third, defect.

In Table 22, it is shown that animals with wry tail were no more or less likely to have screw tail than non-wry tail animals.

Table 22. Comparison of frequency of occurrence of screw tail anomaly with wry tail anomaly.

	Non-screw tail:	Screw tail:	Totals
Non-wry tail	253	61	314
Wry tail	216	47	263
Totals	469	108	577

$X^2 = 0.128$ n.s.
(1 d.f.)

Table 21. Observed twisted face and normal face progeny of ten carrier sires when mated with affected, normal, and unknown cows.

Sire	Total progeny	Twisted face progeny	Progeny from twisted face mates: Twisted	Progeny from twisted face mates: Normal	X_1^2	Progeny from mates w/ normal faces: Twisted	Progeny from mates w/ normal faces: Normal	X_2^2	Progeny from unknown mates: Twisted	Progeny from unknown mates: Normal	X_3^2	X_4^2	X_5^2
A	91	23	3	4	0.143	1	9	1.200	19	55	17.512	0.018	0.305
B	67	16	3	0	3.000	6	23	0.266	7	28	12.600	0.492	0.162
C	49	9	1	4	1.800	1	9	1.200	7	27	11.764	0.353	0.163
D	42	9	0	3	3.000	4	9	0.265	5	21	9.846	0.461	0.217
E	31	8	1	3	1.000	2	7	0.024	5	13	3.554	0.073	0.321
I	11	1	0	1	1.000	1	1	0.666	0	8	8.000	2.667	2.323
K	36	12	1	1	0.000	1	1	0.666	10	22	4.500	0.667	1.646
L	12	2	0	1	1.000	2	1	2.455	0	8	8.000	2.667	2.323
M	14	1	0	1	1.000	0	1	0.250	1	11	8.332	1.777	1.509
N	10	2	0	1	1.000	1	2	0.064	1	5	2.666	0.222	0.149
Totals	363	83	9	19		19	63		55	198			
X^2 (9 d.f.) (Total)					12.943			7.056			86.774*	9.397	9.118
"Goodness of Fit" X^2 (1 d.f.)					3.572			0.146			80.826*	1.418	0.201
Heterogeneity X^2 (8 d.f.)					9.371			6.910			5.948	7.979	8.917

Assume mates:

1 = to be all recessive homozygotes

2 = to be all carriers

3 = to be all affected

4 = to be all carriers

5 = to possess the gene frequency obtained from this study (0.46)

In Table 23, it is shown that animals with a wry tail were no more or less, likely to have a twisted face than non-wry tail animals.

Table 23. Comparison on frequency of wry tail anomaly with twisted face anomaly.

	Normal face:	Twisted face:	Total
Normal tail	253	61	314
Wry tail	200	63	263
Total	453	124	577

$X^2 = 1.490$ n.s.
(1 d.f.)

In Table 24, it is shown that animals with a screw tail were no more, or less, likely to have a twisted face than non-screw tail animals.

Table 24. Comparison of frequency of screw tail anomaly with twisted face anomaly.

	Normal face:	Twisted face:	Total
Normal tail	370	99	469
Screw tail	83	25	108
Total	453	124	577

$X^2 = 0.271$ n.s.
(1 d.f.)

In Table 25, it is shown that animals with a tail defect were no more, or less, likely to have a twisted face than normal tail animals.

Table 25. Comparison of frequency of an abnormality of the tail occurring with twisted face abnormality.

	Normal face:	Twisted face:	Total
Normal tail	207	46	253
Abnormal tail	246	78	324
Total	453	124	577

X^2 = 2.673 (0.25 > P > 0.10)
(1 d.f.) n.s.

The frequency of occurrence of normal, singly defective and multiply defective animals among the progeny of 23 bulls is shown in Table 26. Only sires with five or more progeny were included. There was no difference in the distribution of normal and affected animals in the various progeny group.

The evidence presented here may be interpreted as indicating that the three characters are probably genetically independent.

Association of Age with Frequency of Abnormalities

In several species, both age of dam when offspring were born and age of animal when observed have been found to be associated with the frequency of abnormalities. The possible existence of such relationships in these data was examined.

<u>Age of Dam</u>. It has been shown in man and other species that older mothers or parous mothers are somewhat more likely

Table 26. Sires listed with progeny which have none, one, two or three of the following anomalies -- wry tail, screw tail, and twisted face.

Sire	Affected Progeny: 0 anomaly	1 anomaly	2 anomalies	3 anomalies	Total progeny
A	28	46	15	2	91
B	28	27	12	0	67
C	21	18	10	0	49
D	18	20	4	0	42
E	12	15	4	0	31
F	5	9	2	0	16
G	3	8	3	0	14
H	2	6	4	0	12
I	6	3	2	0	11
J	6	8	1	0	15
K	11	15	8	2	36
L	5	6	1	0	12
M	4	5	5	0	14
N	5	3	2	0	10
O	5	9	5	0	19
P	3	4	2	0	9
Q	5	3	1	0	9
R	3	2	3	1	9
S	2	3	2	1	8
T	0	5	2	1	7
U	1	4	1	0	6
V	3	0	2	0	5
W	3	0	2	0	5
All others	28	37	11	4	80
Total	207	256	104	10	577

X^2 = 45.718 n.s.
(69. d.f.)

to have defective offspring of certain types than younger mothers or nulliparous mothers. The age of the dam at the time her observed progeny was calved was calculated in months. The frequency of occurrence of wry tail among progeny of dams of different ages is presented in Table 27. The results show that no relationship existed between the age of the dam and the occurrence of wry tail in the progeny.

Table 27. The association of age of dam with the occurrence of wry tail in progeny.

Age of dams (months)	Number wry tail progeny	Number non-wry tail progeny	Total	Percent affected
21-40	76	95	171	44.44
41-60	68	82	150	45.33
61-80	40	53	93	43.01
81-100	34	32	66	51.51
101-120	23	23	46	50.00
121 --	13	13	26	50.00
	254	298	552	46.01

X^2 = 2.108 n.s.
(5 d.f.)

In Table 28, the incidence of screw tail among progeny of dam of different ages was examined. The frequency of screw tail did not differ significantly among the age groups.

The number of twisted face progeny differed statistically from that expected for the various age groups as shown in Table 29. However, this deviation did not show a definite trend with age. The greatest variation from expected occurred among progeny of cows that were in the 61 - 80 months and 121 months or more groups. Both groups were severely deficient in the number of screw tail progeny. The reasons for these apparent deficiencies are unknown.

Table 28. The association of age of dam with the occurrence of screw tail in progeny.

Age of dam	Number screw tail progeny	Number non-screw tail progeny	Total progeny	Percent affected
21-40	30	141	171	17.54
41-60	21	129	150	14.00
61-80	22	71	93	23.65
81-100	13	53	66	19.69
101-120	9	37	46	19.56
121 --	6	20	26	23.07
	101	451	552	18.29

X^2 = 3.717 n.s.
(5 d.f.)

Table 29. The association of age of dam with the occurrence of twisted face in progeny.

Age of dam	Number twisted face progeny	Number non-twisted face progeny	Total progeny	Percent affected
21-40	45	126	171	26.31
41-60	33	117	150	22.00
61-80	10	83	93	10.75
81-100	17	49	66	25.75
101-120	15	31	46	32.60
121 --	1	25	26	3.84
	121	431	552	21.92

X^2 = 17.452** $P < 0.005$
(5 d.f.)

All affected progeny were considered collectively to determine if age of dam influenced the incidence of any one or combinations of all three defects. While some increase in the percent of affected progeny was noted as the dams increased in age, this difference was not statistically significant. The results are presented in Table 30.

Table 30. The association of age of dam with the occurrence of wry tail, screw tail, and twisted face, or any combination of these defects among progeny.

Age of dam	Total affected progeny	Total non-affected progeny	Total observed	Percent affected progeny
21-40	108	63	171	63.15
41-60	92	58	150	61.33
61-80	58	35	93	62.36
81-100	48	18	66	72.72
101-120	34	12	46	73.91
121 --	16	10	26	61.53
	356	196	552	64.49

$X^2 = 5.80$ n.s.
(5 d.f.)

<u>Age of Animal</u>. It has been suggested that these defects might occur more frequently among older animals. This assumption might be interpreted to mean that although these defects may be present in immature animals, they have not developed to such an extent that they are easily detected. It is shown in Table 31

that the age of the animal was not associated with the incidence of wry tail.

Table 31. Frequency and percent of wry tail animals observed in various age groups.

Age groups (months)	Wry tail	Non - wry tail	Total observed by age groups	Percent of wry tail by groups
21-40	52	72	124	41.93
41-60	72	86	158	45.57
61-80	53	52	105	50.48
81-100	45	52	97	46.39
101-120	24	21	45	53.33
121 --	13	18	31	41.93
	259	301	560	46.25

$X^2 = 2.384$ n.s.
(5. d.f.)

Frequency of screw tail was not the same for all age groups. It appears that a pronounced trend toward greater frequency of screw tail among older animals exists. Even when regrouping these age groups into three groups, a significant difference was still found. In a three age-group breakdown, the percent of screw tail cows was 9.6 percent, 21.7 percent and 43.4 percent. The association of age with occurrence of screw tail is shown in Table 32.

Table 32. Frequency and percent of screwtail observed in various age groups.

Age groups (months)	Screw tail	Non-screw tail	Total observed by age groups	Percent of screw tail by groups
21-40	13	111	124	10.48
41-60	14	144	158	8.86
61-80	20	85	105	19.04
81-100	24	73	97	24.74
101-120	22	23	45	48.89
121 --	11	20	31	35.48
	104	456	560	18.57

X^2 = 52.25 **
(5 d.f.)

The frequency of the twisted face defect did not differ significantly for any age groups. No trends were observed. This is shown in Table 33.

Table 33. Frequency and percent of twisted face character in various age groups.

Age groups (months)	Twisted face	Non-twisted face	Total observed by age groups	Percent of twisted face by groups
21-40	28	96	124	22.58
41-60	31	127	158	19.62
61-80	23	82	105	21.90
81-100	20	77	97	20.61
101-120	14	31	45	31.11
120 --	7	24	31	22.58
	123	437	560	21.96

X^2 = 2.556 n.s.
(5 d.f.)

Animals possessing one or more defects were classified as defective. Then the frequency of defective animals in different age groups was examined. An increase in anomalies was observed in the older age groups. These results are statistically significant at the 0.05 level, and indicate that age may have some influence on the incidence of these anomalies collectively.

Table 34. The effect of age on the occurrence of wry tail, screw tail, twisted face, or any combination of these defects.

Age observed (months)	Total affected	Total not affected	Total observed	Percent affected
21-40	74	50	124	59.68
41-60	94	64	158	59.49
61-80	75	30	105	71.43
81-100	66	31	97	68.04
101-120	38	7	45	84.44
121--	19	12	31	61.29
	366	194	560	

$X^2 = 12.474^*$ $P < 0.05$
(5 d.f.)

DISCUSSION

Wry Tail

The data included in this study were sufficient to exclude the possibilities that all wry tails were inherited as simple recessive traits or as simple dominant traits. Thus the two simplest genetic explanations have been excluded. Several alternative and more complex explanations were examined. These were: a. that wry tail was produced by the action of two independent genes; b. that wry tail was produced by the action of a single pair of genes, with one of the alleles being incompletely penetrant; and c. that some wry tails may result from environmental causes.

With the exception of duplicate recessive epistasis, all of the two-pair hypotheses adopted and examined were readily excluded. If the matings of one wry tail bull and four wry tail cows that produced four normal tail progeny could have been excluded for some logical reason, the remainder of the mating results might have fitted some one of the excluded two-pair hypotheses. Although errors might have been made in observing and recording these matings, none of these possibilities were accepted inasmuch as they cast doubt on the accuracy of the remaining data.

The two remaining hypotheses, incomplete penetrance and environmentally-produced wry tail, both quite difficult to test, were tested tangentally.

The assumption of an incompletely penetrant recessive gene required a gene frequency in excess of 0.67, (the frequency estimated in this study), whereas the incompletely penetrant dominant gene hypothesis only required a frequency in the range from 0.30 to 0.67. The incompletely dominant gene theory should be looked upon as a possible hypothesis to be tested.

The possibility of wry tail having been caused by some unknown or unidentified environmental cause or causes was examined. Several bits of evidence supported this possibility. Huston (8) in unpublished study of these data, found the heritability of wry tail to be 0.265. He interpreted this as signifying that wry tail, while heritable, was primarily caused by non-additive genetic factors or environmental factors, as yet unidentified.

Also, the appearance of wry tail progeny with equal frequency from wry tail and normal dams suggested that environmental causes must play an important role in the wry tail character. This view was further strengthened by the fact that every bull with three or more observed progeny had at least one wry tail daughter.

Although tails wry to the right were significantly more frequent than those set to the left, this trait occurred with no greater frequency in the progeny from either wry right or wry left cows. Since normal cows did not show a greater occurrence of wry right or wry left tail in their progeny, it would seem that the direction of tail set is purely a chance event.

Lastly, there seemed to be no physiological or anatomical theory that might offer some explanation for the occurrence of wry tail. If the ossification processes in the cow are similar to those in the horse, one might suppose that wry tail appears shortly after the ossification of the median sacral crest and as a result of some disturbance in this process. One might also suppose that wry tail might be due to injury of the tail or to aging of the muscles of the tail. Neither of these suppositions proved to be valid inasmuch as wry tail animals occurred with equal frequency in the several age groups. As a last resort, one might suppose that parity or aging of dam might have some association with the frequency of occurrence of wry tail in her progeny. This was shown not to be the case.

It appears likely that considerable additional study will be required to secure a satisfactory explanation of the causes of wry tail.

Screw Tail

The screw tail defect did not conform to the simple recessive mode of inheritance because of the scarcity of affected progeny, as opposed to the excess found for wry tail. The dominant mode of inheritance was ruled out because two normal parents produced screw tail offspring.

Normal dams produced as high a proportion of screw tail progeny as screw tail dams. This fact suggested that this character is not highly heritable. Although this character was relatively infrequent among progeny of sires, six of nine progeny observed from one sire had screw tails. The sire was of unknown phenotype, as were all but one of the mates. However, this dam possessed the screw tail defect. Environmental factors were suspected to cause screw tail because the percentage of screw tail in older animals was higher than the percentage in younger animals. Even though the original six age groups were re-grouped into three groups, a significant association of age with screw tail was found. The percentage of animals affected in each of the three age groups were as follows: for animals 21 to 60 months of age - 9.6 percent; for animals 61 to 100 months of age - 21.7 percent; and for animals older than 101 months - 43.4 percent. The cause of this association is conjectural.

Among 24 heifers sired by one bull, the only nulliparous females examined in this study, no screw tail animals were found. If Sisson and Grossman's (15) observation that the coccygeal vertebrae tend to fuse in old horses has an analogue in the cow, this might be an explanation for the increased frequency of screw tail animals among the older animals. There was no association between age of the dam and the incidence of screw tail.

Twisted Face

The twisted face anomaly conformed to all tests for the simple recessive mode of inheritance. Therefore, at least for the data of this study, the twisted face defect was considered as a simple recessive trait. Although the incidence of faces twisted to the left was greater than that of faces twisted to the right, cows with faces twisted either left or right did not produce significantly more progeny with faces twisted in the corresponding direction. As with the wry tail character, the direction of twist seemed to be a chance event. Also, since twisted face dams did not produce a significantly greater proportion of twisted face progeny than normal face dams, this trait was considered not to be highly heritable. Twisted face was not found to occur with equal frequency among the progeny of cows of different ages. Cows of 61 to 80 months of age and 121 or more months of age produced fewer twisted face offspring than dams of other ages.

Occurrence of More than One Defect in the Same Animal

Although some work with other species, as well as personal observation, suggests that characters might occur more frequently together than separately, this was not found to be true with any of these three anomalies. When analyzed statistically, there was no correlation between the frequencies of any two or more of these characters. The distribution of total anomalous animals among the progeny of each sire followed a similar pattern.

Practical Considerations of these Defects

Control of these three defects might be considered as typical of the problems of purebred breeders who are trying to breed cattle of uniform body conformation. Likewise, this herd gives evidence that even without intensive inbreeding, a herd can become more seriously affected with one or several defects than the average herd of the breed. Thus, control of the defect(s) becomes of considerable economic importance. Breeders should be ever alert for the occurrence of defects which may appear in a breed.

Problems of control are complicated by the fact that these characters are often inherited either as recessives or in a more complex manner.

SUMMARY AND CONCLUSIONS

Five hundred and seventy-seven Jersey cows in one herd were observed for three defects - wry tail, screw tail, and twisted face. Of the entire group of cows, 263 possessed the wry tail defect, 107 possessed the screw tail defect, and 124 possessed the twisted face defect. Two hundred and seven cows did not possess any of these three defects, while 370 had one or more defects. Of the 370 affected cows, 256 had only one defect, 104 possessed two defects, and 10 cows had all three defects.

The manner in which wry tail was inherited was not determined. However, the possibility of either a simple recessive, a simple dominant, or one of several two-pair modes of inheritance was ruled out. The possibility that it was inherited as an incompletely penetrant dominant trait was not eliminated.

The frequency of wry right tails was significantly greater than wry left tails. The direction of the tail set of wry tail progeny was not associated with the direction of the tail set in their dams. Normal tail dams produced wry right and wry left tail progeny in equal frequencies. It was concluded that wry right and wry left tail set was purely a chance event. Wry tail dams did not produce more wry tail progeny than did normal dams. Neither age of dam nor age of the individual was associated with the incidence of wry tail. All sires (59) which had three or more progeny observed had at least one wry tail progeny.

The occurrence of screw tail was too infrequent to conform to a simple recessive type of inheritance. A dominant mode of inheritance was also eliminated. However, the possibility of an incompletely penetrant dominant was not ruled out. Screw tail dams did not produce more screw tail progeny than did normal dams. Age of dam was not associated with the incidence of screw tail in the progeny. Screw tail animals occurred with increasingly greater frequency among increasingly older groups of animals. The cause of this association is conjectural.

The twisted face defect was thought to be inherited as a simple recessive. The direction of twist, left or right, appeared to be a chance event. Twisted face progeny did not occur more frequently from twisted face dams than did normal face progeny. Twisted face progeny occurred less frequently in the progeny of dams of 61 to 80 months of age and of 121 months or more of age than from other age groups. Age of the animal was not associated with the incidence of twisted face.

The age of dam was not associated with the occurrence of defective progeny. The incidence of all defects considered, collectively, occurred with increased frequency in increasingly older groups of animals.

There was no association in the occurrence of any two or more of these three defects.

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FREQUENCY OF AND MODE OF INHERITANCE
OF WRY TAIL, SCREW TAIL AND TWISTED FACE
IN A HERD OF JERSEY CATTLE

by

MORRIS BRILEY EWING

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The purpose of this study was to determine the mode of inheritance of three body conformation defects, wry tail, screw tail, and twisted face. In addition, further study concerning the relationship of these defects, their apparent frequencies, and the occurrence of variations in their frequencies among animals of different ages was made.

The data used in this study were obtained on a single herd of 577 Jersey cows. These data were part of a larger body of data collected by F. W. Atkeson and F. E. Eldridge during the period from July 1st to July 5th, 1950. All adult animals were examined for these three defects. Five herd sires were also examined for these defects, but were not included in the total.

Of the 577 cows analyzed for the data which were collected, 263 cows possessed the wry tail defect, 107 possessed the screw tail defect, and 124 possessed the twisted face defect. Two-hundred and seven cows did not possess defects while 370 had one or more defect. Of the 370 affected cows, 256 had only one defect, 104 possessed two defects, and 10 possessed all three defects.

The manner in which wry tail was inherited was not determined. However, the possibilities of it being either a simple recessive, a simple dominant, or one of several two-pair modes of inheritance, were ruled out. The possibility that it was inherited as an incompletely penetrant dominant trait was not eliminated. The direction of the tail set of wry tail progeny was not associated with the direction of the tail set in their dams. It was concluded that wry right and wry left tail set was a purely chance event. Wry tail dams did not produce more wry tail progeny than did normal dams. Neither age of dam nor age of individual was associated with the incidence of wry tail. All sires (59) which had three or more progeny observed had at least one wry tail progeny.

The screw tail trait did not conform to a simple recessive mode of inheritance. A dominant mode of inheritance was also eliminated. However, the possibility of an incompletely penetrant dominant was not ruled out. Screw tail dams did not produce more screw tail progeny than did normal dams. Age of dam was not associated with the incidence of screw tail. Screw tail animals occurred with greater frequency among increasingly older groups of animals. The cause is conjectural.

Twisted face defect was found to be inherited as a simple recessive. The direction of twist, left or right, appeared to be a chance event. Twisted face progeny did not occur more frequently from twisted face dams than did normal face progeny. Twisted face progeny occurred less frequently in the progeny of dams of 61-80 months of age and of 121 months or more of age, than from other groups. Age of the animal was not associated with the incidence of twisted face.

The age of dam was not associated with the occurrence of defective progeny. The incidence of all defects considered collectively occurred with increased frequency in increasingly older groups of animals.

There was no association in the occurrence of any two or more of these defects.