THE INHERITANCE OF COLOR AND HORNS IN ALASKAN HYBRID GALLOWAY-HOLSTEIN CATTLE

by

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INTRODUCTION

The Alaska Agricultural Experiment Stations, confronted with the problem of procuring a hardy dairy cow for the northern agricultural lands of Alaska began the reciprocal crossing of hardy Galloway beef cattle and Holstein dairy cattle, in 1917, at its Kodiak Station. The work was carried on at that station until 1926, when the herds were transferred to the interior Alaska Station at Matanuska, where the work was continued until 1932. As stated above, the primary purpose of the experiment was the production of a hardy dairy cow.

Considerable progress had been made in this respect, when the work was discontinued as a federal project. The original Holstein dams with which the hybridizing work was started, were mediocre cows, producing 5000-8000 pounds of milk, while the parent Galloways were producing milk testing 4 per cent to 6 per cent butterfat. A number of cows and heifers of the F_2 and F_3 generations, giving 10,000 to 14,500 pounds of milk testing 4 per cent fat and more, were being milked when the work was abandoned as a federal project. This amount of milk produced by the better hybrids was nearly twice that of their highest parental dams, while the percentage of fat was intermediate between that of the two parent breeds.

The problem, as originally outlined, was purely a practical one in which no provision was made to obtain particular data upon the numerous theoretical genetic factors involved. However, the author who was in charge of the work for 13 years as Animal Husbandman was able to obtain considerable data from the records. To these are added observations and data taken on his own responsibility. These are presented herewith as evidence on color and horn inheritance and should be of general genetic interest. While the data are taken from the animals and records of the United States Department of Agriculture, the author must assume full responsibility for their correctness, the interpretations made, and the conclusions drawn therefrom. Data upon color and horns only will be summarized in this paper. A number of points relative to the inheritance of other factors were noted and data concerning them recorded. These studies will be offered for publication at a later date when time is available to work upon the material. Mention of them is made in this discussion, however, as a point of general interest.

THE FOUNDATION HERD

Galloways

The Galloway breed in the United States is considered as a breed to be solid black in color. Gourley (1919) points out that the breed in its native Scotland was formerly of various colors, but is now bred only from black animals. While a limited amount of white in the inguinal region and along the underline is permitted in animals registered in the Galloway herd book, animals carrying more than this limited amount are barred from registry. That purebred Galloway cattle may carry factors for white in addition to inguinal white, in at least the heterozygous state, is indicated in the data given later in this paper. The Galloways are also a polled breed, and no horns are recorded as appearing in the breed for many years. So strongly has the polled condition been associated with the breed that the appearance of horns among even F_1 hybrid or grade Galloways has often raised the question of the purity of the original Galloways entering the cross. No horns appeared in the Alaska Galloways (Plates IV, V, and VI). A list of the purebred Galloways used in this experiment is found in Table 1, part a.

Table 1. Parent Herd

(a) Galloway Cattle

Alaskan Herd No.	Name	Reg. No.
	COWS	
10	Mollie C. of Red Cloud	26239
71	Millie 3rd of Kodiak	34911
123	Miss 2nd of Kodiak	40338
140	Bertha A	34889
147	Hattie B	32416
187	Fidelia 4th of Kodiak	40335
209	Lady May of Kodiak	41738
215	Fidelia 6th of Kodiak	41730
246	Maggie of Kodiak	45143
247	True Beauty 3rd of Kodiak	45138
252	Mollie 8th of Kodiak	45146
277	Jaynes Banshee	48193
293	Miss of Red Cloud's Girl	48148
	BULLS	
163	Carnot of Kodiak	39139
218	Prince Douglas 3rd of Kodiak	45136
303	Ranger of Seven Oaks	45044
329	Aberdeen	2646*

(b) Holstein Cattle

Alaskan Herd No.	Name	Reg. No.
	COWS	
2H	Cascade Betsy	154663
3H	Cascade Betsy 2nd	260870
4H	Miss Gladys Cornucopia	336455
5H	Grandview Fayne Piebe Johana	233446
6H	Gladys Mercedes Banks	336456
9H	Gladys Mercedes Banks 2nd	596282
13H	Kodiak Mercedes Banks	596283
16H	Betsy Chimacum Cornucopia	692342
25H	Miss Gladys Shadford	963107
	BULLS	
1H	Chimacum Sir Quirinus Cornucopia	176468
7H	Islander	(Eligible to registry)
20H	Shadford Segis Hartog 2nd	352564
35H	Heilo Pontiac King	519811

* Canadian herd book registry.

Holsteins

Holstein breeders consider it highly desirable for their black-and-white cattle to carry a considerable amount of white. Especially desirable in the Holstein breed are white legs and underline, as well as some white on the head, generally a star or blaze pattern, and a white switch. No definite pattern of these black-and-white body markings is required, but the distribution according to a number of breeders should be about equal amounts of white and black, either in spots of varying size, or irregular patterns of no particular design. Some strains of this breed are practically all white (Dunn, Webb, and Schneider, 1923), while others are practically black except for white legs and underline. Breeders of Holsteins as a rule prefer more white than black in their animals. However, the Alaskan Holsteins were generally characterized by a predominance of black (Plates I, II, and III). A number of them had little white above the underline, except the switch and tongue, which were white in all cases. These animals were purchased from various breeders on the Pacific coast. They were purposely selected for black, inasmuch as it was desired that the new breed be black in color. Moreover, funds allowed for the purchase of this herd were limited and it was believed that Holsteins carrying much black, of equal quality in other respects, could be purchased for less than could animals carrying the desirable amount of white. Holsteins are a horned breed. No authentic cases are found in the literature of polled individuals. The breed is considered by breeders to be homozygous for the factor producing horns. Further evidence showing the monohybrid behavior of polled versus horns as a simple allelomorphic pair of genes is given in this discussion. The parent Holsteins used in this experiment are listed in Table 1, part b.

GENERAL DISCUSSION

Geneticists have identified a number of color factors in all of the more common breeds; one of the earliest factors to be worked out was that of white and red (Laughlin, 1912) in which it is assumed that the gene for red is carried by all cattle, and will express itself as a red coated animal unless modified by white pattern factors or when the red is masked by black (Cole and Jones, 1920). This is the situation in the case of black cattle. The red is present but is masked by black; that is, black will mask red but not the white the animal may carry. Thus we postulate B for black color and when carried by an individual causes the animal to be black in color, and b for non-black when the animal generally appears as some shade of red. The shade of red or black carried by any animal is governed by special modifying genes with which we do not attempt to deal in this paper.

Likewise, two allelomorphic genes are responsible for either the solid color condition (called self, either black or red) or the white-spotted or "pied" condition, where the animal is either black with white spots or red with white spots. We shall attempt to establish the above allelomorphic relationship by ample proof in this paper.

The appearance of a self colored animal may be modified by the presence of a dominant white-spotting gene, such as inguinal white (In), which causes a white spot to appear in the inguinal region. Similarly, the amount of white shown by an animal homozygous for recessive white-spotting (s) may be greatly influenced by modifiers, such as "little white" (Lw), and "pigmented leg" (Pl).

EXPERIMENTAL RESULTS

The Galloway breed has been widely described as self black. It has generally been claimed that when bred inter se no white other than inguinal white would appear. The mode of inheritance of inguinal white has been suggested by Gowen (1918). However, little is recorded as to its genetic behavior with reference to the amount and location of the white. Inguinal white often is difficult to perceive in animals that are otherwise self colored unless the animal is thrown (cast). Galloways are able to transmit their black coat to their offspring in at least a large percentage of cases when they are crossed with either red or recessive white-spotted cattle. This latter fact has been responsible for the rather wide-spread belief that they are homozygous for the two dominant factors self (S) and black (B); we have no reason to believe otherwise for a large part of the breed. But there is evidence that some individuals at least are heterozygous for one or the other factor, or for both. We are concerned, however, only with the behavior of self versus white-spotting, in this paper.

The appearance of a few animals in the Alaska Galloway herd carrying what seemed to be excessive inguinal white aroused suspicion in the minds of some of the men connected with the work of the possibility that these Galloways were carrying the white-spotting factor (s), but that minus modifiers reduced the white to a minimum. Another possibility was that self was incompletely dominant to white-spotting and, therefore, these animals were heterozygotes. A third possibility was that these were self animals carrying inguinal white and that the amount of white had been greatly increased by means of plus modifiers.

While no extensive definite test matings were made within the Galloway breed with these points in view, one mating was made which indicates that a number of individuals in the purebred Galloway herd were heterozygous selfs (Ss). For example, when the Galloway bull 303 was bred to five Holstein cows (Table 2), three of the five calves (Nos. 14, 15, and 22) were observed to carry white-spotting. Later, another Galloway bull, No. 329, imported from Canada and believed to carry white-spotting, was bred to two Holstein cows. The two hybrid calves, No. 52 and No. 66 (Table 2) showed only enough white so that they were listed as carrying inguinal white. However, when this same Galloway bull was mated to a Galloway cow carrying, for a Galloway, a large amount of white on the underline, heifer 349 was produced, with a full white underline, a white tongue, and a white tipped switch, fairly conclusive evidence that she was ss. The bull 329 later was bred to a hybrid self black Galloway-yak cow, his daughter. The calf had a star on the forehead and a large amount of white on the underline, further evidence that No. 329 was heterozygous (Ss).

There is also evidence that a Galloway cow, No. 247, was a heterozygous self. Her one mating with the Holstein bull 1H (Table 2), resulted in a bull calf, No. 11, with

Table 2. Twenty-five Reciprocal Galloway and Holstein Matings

Sire P_1	Dam P_1	Offspring* F_1
Galloway	Holstein	
163 Black polled	5H Spotted horned	♀ 5 Black polled
218 Black polled	5H Spotted horned	♂ 8 Black polled
163 Black polled	3H Spotted horned	♂ 6 Black polled
303 Black polled	6H Spotted horned	♀ 14 Spotted polled
303 Black polled	9H Spotted horned	♂ 15 Spotted polled
303 Black polled	2H Spotted horned	♂ 22 Spotted polled
303 Black polled	4H Spotted horned	♀ 30 Black polled
303 Black polled	13H Spotted horned	♂ 40 Black polled
329 Black polled	25H Spotted horned	♀ 52 Black polled
329 Black polled	16H Spotted horned	♂ 66 Black polled
Holstein	Galloway	
1H Spotted horned	71 Black polled	♀ 1 Black polled
1H Spotted horned	147 Black polled	♂ 2 Black polled
1H Spotted horned	187 Black polled	♀ 3 Black polled
1H Spotted horned	10 Black polled	♀ 4 Black polled
1H Spotted horned	246 Black polled	♂ 7 Black polled
1H Spotted horned	247 Black polled	♂ 11 Spotted polled
1H Spotted horned	277 Black polled	♀ 16 Black polled
1H Spotted horned	209 Black polled	♂ 17 Black polled
1H Spotted horned	293 Black polled	♀ 18 Spotted polled
1H Spotted horned	215 Black polled	♂ 19 Black polled
1H Spotted horned	123 Black polled	♂ 20 Black polled
1H Spotted horned	140 Black polled	♀ 21 Black polled
20H Spotted horned	215 Black polled	♀ 28 Black polled
1H Spotted horned	252 Black polled	♂ 33 Black polled
20H Spotted horned	246 Black polled	♀ 39 Black polled

* 20 Black polled
5 Spotted polled

white underline, switch, and tongue, that left little doubt but that the calf was a homozygous recessive (<u>ss</u>). A fourth case appeared when the Galloway cow 293 bred to the Holstein bull 1H (fig. 1) produced the hybrid F_1 heifer, No. 18 (fig. 19), exhibiting white above the underline at the flanks, a white tongue, and a white switch. This heifer, No. 18, was later bred three times to her self half brother on the sire side, F_1 No. 33 (fig. 15), and produced one self black and two white-spotted calves. When she was backcrossed to Holstein 20H, she dropped a white-spotted heifer, No. 34. The latter was twice bred to the F_1 (<u>Ss</u>) bull 33 and produced two self black heifers, Nos. 62 and 73, but when bred to a Holstein bull produced a white-spotted calf.

While the data obtained could not be construed as conclusive proof that the entire strain of Galloways owned by the Department of Agriculture carried the white-spotting factor there can be no question but that at least some of the animals entering into this experiment were of the composition <u>Ss</u>. The Galloway bull 163, sire of the F_1 hybrids 5 and 6, and the Galloway bull 218, sire of the hybrid F_1 8 are believed to be homozygous for self (<u>SS</u>). Likewise 11 additional Galloway cows, bred one or more times to Holstein bulls, and producing 13 hybrid calves as a part of this experiment, as well as being bred one or more times to the heterozygous (Ss) Galloway bull No. 303, gave no evidence of carrying the spotting factor. These are judged to be homozygous selfs, though it is admitted that a sufficient number of critical matings to determine this conclusion are lacking.

Evidence of Presence of Pigmented Leg Gene, Pl, in Galloways

Another color factor not generally considered in connection with either the Holstein breed or the Galloway breed is pigmented leg. Pigmented leg (Pl) has been postulated (Ibsen and Riddell, 1931) as a dominant modifier of white-spotting (s). Typically its effect is that of causing pigmentation to extend upward from the hoofs on all four feet, particularly along the back of the leg. It also has been postulated as increasing the amount of pigment in other white areas, as in the instance of the Hereford, causing an otherwise white-faced animal to become "brockle-faced."

The first individual in this experiment to show pigmented leg was the backcross male calf, No. 12 (fig. 34) sired by a purebred Holstein bull, upon the F_1 No. 1 hybrid cow. It also appeared in the backcross No. 36 (fig. 33) sired by a Holstein bull, upon the F_1 hybrid cow 5. A third animal showing the character was the white-spotted F_1 hybrid cow 82 (fig. 27). This cow had as a paternal grandsire the Ss Galloway bull 329, referred to above. The pattern shows also in the F_3 female 88 (fig. 30), whose P_1 sire, Galloway 303, appears twice in the third generation lineage.

The Holstein breed could not carry the factor as postulated without allowing it to come to expression. On the other hand, pigmented leg does not show in self animals, such as Galloways, due to the epistacy of S to Pl; but its presence in Galloways is made evident in the white-spotted (s) descendants.

White-restriction (Wr), a Dominant Modifier of White-spotting, s, Carried by Galloways

The proportion of black to white carried by many of the Holsteins used in this experiment was greater than is usually found in the average herd of Holsteins in this country (see figs. 2 and 5).

A number of possible factors influencing the amount of white-spotting in Holsteins has been suggested by various authors, but to date little critical evidence has been produced to prove their exact effects. Dunn, Webb, and

Schneider (1923) postulate a single pair of modifiers of white-spotting, in which Lw (small amount of white) is incompletely dominant to lw (large amount of white). Most of the Alaska Holsteins would be classed LwLw, if one adopts the factorial explanation suggested by the above authors.

Since Ibsen and Riddell (1931) suggested the factor pigmented leg (Pl) as a second modifier of white-spotting carried by some animals of the spotted breeds which they have observed, no further evidence is recorded in the literature. Additional evidence, however, is available in this experiment supporting the existence of pigmented leg (Pl) and Lw, besides other quantitative modifiers of white-spotting.

There appears to be ample evidence to justify the proposal of at least one additional modifier. We propose Wr as a white-restriction factor normally carried by the Galloway and possibly other breeds such as the Shorthorn. When it is present the amount of white-spotting is appreciably reduced. Evidence for the new postulated dominant modifier is as follows.

First, the F_1 ss cows, No. 14 and No. 18, as well as the F_1 males 11, 15, and 22, while showing evidence of carrying the s factor for white-spotting, carried a greatly reduced amount of white, compared with their Holstein parents. The Holstein bull 1H, sire of Nos. 11 and 18, was classified as Lwlw, having an intermediate amount of white. The Holstein dams of Nos. 15 and 22 were largely black and were classified as LwLw, while the Holstein dam (No. 6H) of No. 14 was largely white and was classified as lwlw. Thus, Nos. 11 and 18 should have been either LwLw, Lwlw, or lwlw, while Nos. 15 and 22 should have been either LwLw or Lwlw, and No. 14 (fig. 20) either Lwlw or lwlw. None of these animals, however, showed as much white as their Holstein parents, due we believe to the Wr modifier contributed by the Galloway parents. Only No. 14 and No. 18 of this group were tested by further breeding. No. 18 produced two white-spotted calves by the Ss bull 33 (Tables 3 and 4); both showed the white restricted. Likewise when No. 18 was bred to the LwLw Holstein 20H, female 34 was produced. She was later shown to be ss, although the amount of white carried was very small. Cow No. 14 produced only one white-spotted calf, ♂ No. 74 (fig. 29), in five matings with Ss bulls, but this calf carried as much white as No. 6H, its lwlw Holstein grand-dam. The calf, therefore, should be lwlw wrwr plpl. No opportunity was afforded to test it by further breeding.

Other evidence of the presence of the Wr gene was afforded by the matings of white-spotted F_1 females with

Table 3. Twenty-nine Matings of Hybrid F_1 Bulls X Hybrid F_1 Cows

Sire F_1	Dam F_1	Offspring* F_2
6 Black polled	3 Black polled	♂ 23 Spotted horned
6 Black polled	1 Black polled	♂ 24 Black polled
6 Black polled	5 Black polled	♂ 25 Black horned
6 Black polled	3 Black polled	♀ 26 Black polled
6 Black polled	5 Black polled	♀ 27 Black polled
6 Black polled	1 Black polled	♀ 29 Black polled
6 Black polled	3 Black polled	♀ 31 Spotted horned
6 Black polled	14 Spotted polled	♀ 32 Black polled
33 Black polled	14 Spotted polled	♀ 42 Black horned
33 Black polled	5 Black polled	♀ 44 Black polled
33 Black polled	18 Spotted polled	♀ 45 Black polled
33 Black polled	16 Black polled	♂ 46 Black polled
33 Black polled	3 Black polled	♂ 47 Black horned
33 Black polled	21 Black polled	♀ 48 Black polled
33 Black polled	14 Spotted polled	♂ 49 Black horned
33 Black polled	3 Black polled	♂ 54 Black horned
33 Black polled	39 Black polled	♂ 55 Spotted polled
33 Black polled	18 Spotted polled	♂ 56 Spotted polled
33 Black polled	16 Black polled	♂ 58 Black polled
33 Black polled	21 Black polled	♂ 59 Black polled
33 Black polled	14 Spotted polled	♀ 65 Black polled
33 Black polled	3 Black polled	♀ 68 Black polled
33 Black polled	16 Black polled	♀ 69 Black polled
33 Black polled	18 Spotted polled	♀ 72 Spotted polled
33 Black polled	14 Spotted polled	♂ 74 Spotted horned
33 Black polled	39 Black polled	♂ A Spotted polled
66 Black polled	16 Black polled	♀ 82 Spotted polled
66 Black polled	52 Black polled	♀ 84 Black horned
66 Black polled	16 Black polled	♀ 94 Spotted polled

*29 F_2, Pp X Pp = 19 polled, 10 horned

21 F_2, Ss X Ss = 15 black, 6 spotted

8 F_2, Ss X ss = 5 black, 3 spotted

heterozygous F_1 self males (Table 4). Here again, the white-spotted offspring showed less white than the Holstein ancestors. In another cross when the Ss bull 46 was mated to three hybrid white-spotted cows, Nos. 82, 88, and 98 (Table 5), one of the offspring, ♂ 105 (fig. 31), showed more white-spotting than his dam, No. 82 (fig. 27), while the other two, ♂ 112 and ♀ 113, carried less white-spotting than their respective dams, Nos. 88 and 98. An inspection of these animals as shown by their photographs makes it apparent, however, that ♀ No. 82 has less white than her son, No. 105, because she is pigmented legged (Pl) and he is not. The fact that he is not pigmented legged also proves that she is heterozygous (Pl pl). Both No. 82 and No. 88 (fig. 30) carried the pigmented leg factor (Pl) as well as Wr. The number of animals dealt with are too small to show the inheritance of Wr, but its occurrence in a number of the white-spotted offspring fits in with the assumption that it is a simple dominant. Ibsen (1933) has pointed out that the Shorthorn breed carries a gene (Rn) which may be identical with, or at least similar to, Wr.

Table 4. Progeny of F_1 (ss) Females by F_1 (Ss) Bulls

Sire F_1	Composition	Dam F_1	Composition	Offspring F_2	Composition Ss	ss
6	Ss	14	ss	♀ 32	Ss	
33	Ss	14	ss	♀ 42	Ss	
33	Ss	14	ss	♂ 49	Ss	
33	Ss	14	ss	♀ 65	Ss	
33	Ss	14	ss	♂ 74		ss
					4	1
33	Ss	18	ss	♀ 45	Ss	
33	Ss	18	ss	♂ 56		ss
33	Ss	18	ss	♂ 72		ss
					1	2
				Grand total	5	3

Table 5. Matings of Ss Black F_2 Bull with ss Cows (not F_1)

Sire	Dam	Offspring	Composition Ss	ss
46 (Ss) Black	31 F_2 Spotted	♀ 116	Ss	
46 (Ss) Black	82 F_2 Spotted	♂ 105		ss
46 (Ss) Black	88 F_3 Spotted	♀ 112		ss
46 (Ss) Black	98 F_2 Spotted	♂ 113		ss
			1	3

Inguinal White (In) in Galloways and Holsteins

Inguinal white, referred to by Gowen (1918), was shown to be inherited as a dominant. Ibsen (1933) suggests the symbol In for the gene. White in the inguinal region has been observed in a number of breeds of cattle, but its positive identification as inguinal white rather than white-spotting (ss) is made difficult in this experiment because of two pertinent facts. The first is the possibility that the factor is carried by the white-spotted as well as by the self-colored breeds, and that, in the former case, its expression may be masked by recessive white (s). At least a portion of the Holsteins which were used in this experiment seem to have carried inguinal white. The second fact is that up to the present the limits of the inguinal white pattern have not been defined. In other words, it is not known to what degree modifiers can affect its shape and size. In the present paper it has been assumed that if the white extended on the underline forward of the navel, or above the flank, it was due to s, and not In. On the other hand, if the white was small in amount, posterior to the navel, and not extending back of the udder or scrotum, it was assumed to be due to In. It is recognized, however, that a S, In animal, with modifiers increasing the amount of white, might have more white than a ss in in animal with modifiers which markedly decrease the amount of white. A border line case is that of the Galloway cow, No. 349. She was assumed at first to be carrying an excessive amount of inguinal white, but later was classified as ss, due mainly to the fact that she had a white switch and white tongue, in addition to the large amount of white in the inguinal region. For the time being it is assumed that S In animals do not have white tongues, or white switches.

Inherited Susceptibility to Mammitis

An interesting case appeared as a possibly inherited physical weakness. The Galloway cow, No. 140, lost the left back quarter of her udder early in her second lactation, due to what was at the time believed to be a chronic case of mammitis. The right back and front quarters were affected and gave no milk in her third lactation, and the remaining left front quarter became non-functional during her fourth lactation. No. 140's female calf, the only female of four calves dropped, hybrid F_1 heifer No. 21 by the Holstein bull 1H, lost one quarter in her first lactation, a second quarter in her second lactation, and the remaining two quarters so early in the third lactation that she had been milked less than 30 days, when she was fattened and slaughtered. No. 21's only female of three calves dropped, the F_2 heifer No. 48, gave 5109.3 pounds of milk in 287 days, her first lactation, which began when she was 33 months old. She seemed perfectly normal when finishing her first lactation except that the lactation period was somewhat short of the usual 365 day-period reached by a number of the F_1 and F_2 heifers. However, beginning with the sixty-third day of her second lactation, an aggravated case of mammitis set in and the entire udder was lost. Both of the calves dropped by No. 48 were males. Except for the three cases noted, no indication of mammitis of such marked virulence was found in any of the other cows bred by the Alaska stations. It would appear that the malady was due to a physical weakness in the individuals exhibiting it, the weakness possibly being due to a dominant factor.

Detailed Description of Matings of <u>Ss</u> F_1 Cows*

<u>F_1 Hybrid Cow No. 1 (Ss) (Black with white on udder.)</u>

Hybrid Cow No. 1 was twice bred to the F_1 hybrid bull No. 6 (Table 6) dropping two female calves, Nos. 24 and 29. The black heifer calf, No. 24, died at two weeks of age so that no opportunity was afforded to test its composition.

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* See Tables 1 and 2 for parents of F_1 animals.

Table 6. Progeny of F_1 (Ss) Females by (Ss) Bulls

Sire	Composition	Dam F_1	Composition	Offspring F_1	Composition S	Composition ss
6 F_1	Ss	1	Ss	♀ 24	S	
6 F_1	Ss	1	Ss	♀ 29	S	
6 F_1	Ss	3	Ss	♂ 23		ss
6 F_1	Ss	3	Ss	♀ 26	S	
6 F_1	Ss	3	Ss	♀ 31		ss
33 F_1	Ss	3	Ss	♀ 47	S	
33 F_1	Ss	3	Ss	♀ 54	S	
33 F_1	Ss	3	Ss	♀ 68	S	
					6	2
6 F_1	Ss	5	Ss	♂ 25	S	
6 F_1	Ss	5	Ss	♀ 27	S	
33 F_1	Ss	5	Ss	♀ 44	S	
					3	0
33 F_1	Ss	16	Ss	♂ 46	S	
33 F_1	Ss	16	Ss	♂ 58	S	
33 F_1	Ss	16	Ss	♂ 69	S	
66 F_1	Ss	16	Ss	♀ 82		ss
66 F_1	Ss	16	Ss	♀ 94		ss
46 F_2*	Ss	16	Ss	♂ 106	S	
					4	2
33 F_1	Ss	21	Ss	♀ 48	S	
33 F_1	Ss	21	Ss	♀ 59	S	
					2	0
33 F_1	Ss	39	Ss	♂ 55		ss
33 F_1	Ss	39	Ss	♂ A		ss
46 F_2*	Ss	39	Ss	♀ 108	S	
46 F_2*	Ss	39	Ss	♀ B	S	
					2	2
66 F_1	Ss	52	Ss	♀ 84	S	
					1	
				Grand total	18	6

*The F_2 bull No. 46 is shown to be of Ss composition in later breedings.

Female No. 29 dropped two black calves, Nos. ♀ 61 and ♂ 70, by the F_1 bull 33, both self black. She also dropped two white-spotted calves, Nos. ♂ 81 and ♀ 98, by the F_2 (Ss) bull 46. The first, a male, No. 81, had white feet, switch, and tongue with a moderate amount of white on the underline and was classified as ss. The second, a heifer, No.98, had white tipped switch, a star in forehead, a white tongue, and a white udder and was classified as spotted (ss). Cow No. 98 backcrossed to her sire, No. 46, produced a white-spotted calf, ♂ No. 113. Thus in the produce of No. 1 there can be identified one female, No. 24, either homozygous or heterozygous for self and one heterozygous (Ss) female, No. 29. Cow No. 1 was also twice backcrossed to Holstein bulls, producing ♂ No. 12 by Holstein sire 7H, and ♂ No. 37 by the Holstein sire 20H. Male No. 12 was a white-spotted calf carrying considerable white, and in addition was pigmented legged (Pl). Male No. 37 was black with a limited amount of white in the inguinal region. Thus, good evidence is available (Table 7) from the backcrosses to show that No. 1 was Ss and also carried Pl (pigmented leg).

Table 7. Backcross Matings of Hybrid F_1 Self Black Cows (Ss) to White-spotted (ss) Holstein Bulls

Sire P_1	Composition	Dam F_1	Composition	Offspring F_2	Composition Ss	ss
7H	ss	1	Ss	♂ 12		ss
20H	ss	1	Ss	♂ 37	Ss	
7H	ss	3	Ss	♂ 9	Ss	
20H	ss	3	Ss	♀ 41	Ss	
20H	ss	5	Ss	♀ 36		ss
20H	ss	16	Ss	♀ 38		ss
20H	ss	21	Ss	♂ 35		ss
				Total ...	3	4

F_1 Hybrid Cow No. 3 (Ss) (Black with white on udder.)

F_1 hybrid cow No. 3 produced two white-spotted calves, ♂ 23 and ♀ 31, and four self black calves, ♀ 26, ♂ 47, ♂ 54, and ♀ 68, by the hybrid F_1 bulls, Nos. 6 and 33. She also produced two self black offspring, ♂ 9 and ♀ 41, when bred to the Holstein bulls, 7H and 20H, respectively, but she produced a white-spotted male when bred to the Holstein bull 35H (fig. 4).

No. 3's white-spotted heifer, 31, (fig. 28) produced three white-spotted calves in three matings to the Holstein bull 35. On the other hand No. 3's self black heifer 26, produced three self black female offspring by the heterozygous self black bull 33, one self black heifer by the F_2 heterozygous self black bull 46, and a self black calf by the Holstein bull 35H. Cow No. 26 was possibly of the composition SS.

F_1 Hybrid Cow No. 5 (Ss) (Black with a small amount of white on fore udder). F_1 hybrid cow No. 5 produced three self black offspring, ♂ 25, ♀ 27, and ♀ 44, by the Ss bulls 6 and 33, and a white-spotted heifer, No. 36, by the Holstein bull 20H. No. 27 was entirely black, while Nos. 25 and 44 had a limited amount of white in the inguinal region. No. 27 produced one self black offspring when bred to the F_1 bull No. 33, and her half sister, No. 44, produced five self black calves in matings with Ss bulls. No. 36 (fig.33) bred five times to a Holstein bull produced five white-spotted calves.

F_1 Hybrid Cow No. 16 (Ss) (Black with white udder). F_1 hybrid cow No. 16 produced 3 self black male offspring, ♂ 46, ♂ 58, and ♂ 69, sired by the F_1 Ss bull No. 33. Both No. 46 and No. 69 (figs. 21 and 24) were retained as breeding bulls, but No. 69 was accidently lost by falling into an abandoned mining shaft when a two year old, after only a few females had been bred to him. No. 46, however, developed into a fine-appearing animal showing considerable dairy quality, and appears as the sire of a large percentage of the later calves of the hybrid herd. No. 46, although a deep black color with a few white hairs on the back of the scrotum, was heterozygous for white-spotting (Ss), as was demonstrated by the production of the white-spotted bull calf No. 105, when mated to his white-spotted half sister, No. 82. Cow No. 16 also produced two white-spotted heifer calves, Nos. 82 and 94, in succession when bred to the Ss F_1 bull 66. When mated to the Holstein bull 20H she produced a white-spotted heifer calf, No. 38, but produced a coal black bull calf, No. 108, with no evidence of white, when bred to her son, No. 46 (Ss).

F_1 Hybrid Cow No. 21 (Ss) (Black, white-spotted udder). F_1 hybrid cow No. 21 produced a self black male, No. 59, and a self black female, No. 48, by the F_1 Ss bull, 33, but a white-spotted bull calf, No. 35 (fig. 32) by the Holstein bull 20H.

F_1 Hybrid Cow No. 39 (Ss) (Black, white on udder). F_1 hybrid cow No. 39 (fig. 16) produced two white-spotted males, No. 55 and A and two self heifers, No. 108 and B, by heterozygous bulls (Ss). The self heifer, B (fig. 25), of a cherry red color, was from the heterozygous self black F_2 bull No. 46. This was the only instance of a red animal appearing among any of the black cattle of the Alaska herds. The two parents unquestionably were heterozygous for red (Bb), and they furnish proof that one or more of the pure-bred F_1 animals were of this composition.

F_1 Hybrid Cow No. 52 (Ss) (Black). F_1 hybrid cow No. 52 produced one black heifer calf, No. 84, by the F_1 hybrid bull No. 66.

Detailed Description of Matings of ss F_1 Cows

F_1 Hybrid Cow No. 14 (ss) (White underline, flank, feet, switch, star, and tongue). F_1 white-spotted (ss) hybrid cow No. 14 (fig. 20) produced four self black offspring, ♀ 32, ♀ 42, ♂49, and ♀ 65 (fig. 23), by the F_1 (Ss) black bulls 6 and 33, and the white-spotted male calf, No. 74 (fig. 29), by the F_1 bull 33.

F_1 Hybrid Cow No. 18 (ss) (White underline, flank, feet, switch, star, and tongue). F_1 white-spotted (ss) hybrid cow No. 18 produced one self black heifer, No. 45 (fig. 22) by the F_1 black (Ss) bull 66, two white-spotted calves, ♂56 and ♂72, by the F_1 black (Ss) bull 33, and one white-spotted heifer, No. 34, when bred to the Holstein bull 20H.

Detailed Description of Matings of F_1 (Ss) Bulls

F_1 Hybrid Bull No. 6 (Ss) (Black with inguinal white). F_1 hybrid bull No. 6 (fig. 14) sired seven calves from Ss cows. Two, Nos. 23 and 31, were spotted (ss), five, ♀ 24, ♂ 25, ♀ 26, ♀ 27, and ♀ 29, were self black, either SS or

Ss.

When bred to the ss hybrid cow No. 14, female No. 32 (Ss) was produced. No. 32, bred twice to F_1 bull 33 (Ss), dropped two self black calves, ♀ 51 and ♂ 60; but when twice bred to a Holstein bull, No. 35H, she produced calves carrying more white than black.

F_1 Hybrid Bull No. 33 (Ss) (Black, small amount of white on scrotum). F_1 hybrid bull 33 (fig. 15) sired 11 calves from Ss cows; three, ♂ 47, ♂ 55, and ♂ A, were spotted (ss), and eight, ♀ 44, ♂ 46, ♀ 48, ♂ 54, ♂ 59, ♀ 68, and ♂ 69, were black, either SS or Ss. When bred to the ss F_1 cows 14 and 18, bull 33 produced seven calves, four of these were spotted (ss), ♂ 49, ♂ 56, ♂ 72, and ♂ 74, and three self black, ♀ 42, ♀ 45, and ♀ 65.

F_1 Hybrid Bull No. 66 (Ss) (Black, white on front of scrotum). F_1 hybrid bull 66 (fig. 17) sired three calves from Ss cows, two of which, ♀ 82 and ♀ 94, were spotted (ss) and one, ♀ 84, self black (SS or Ss).

Detailed Description of Backcross Matings of Purebred Holstein Bulls to F_1 Cows

The purebred Holstein bull, 7H, sired two calves by Ss cows: Male 9 was self black, male 12, white-spotted (Table 7).

The purebred Holstein bull, 20H, sired four calves from Ss F_1 cows; two were self black, ♀ 41 and ♂ 37, and two, white-spotted, ♂ 35 and ♀ 38. Male 20H also sired one white-spotted heifer calf, No. 34, from the ss F_1 cow 18.

Summary of Results in Regard to Self (S) and White-spotting (s)

In the Ss x Ss matings, 21 F_2 offspring (Table 3) were obtained. Six of these were white-spotted and 15 were self black, a very close approximation to the expected ratio of 5.25:15.75. Three additional matings of these F_1 cows to the F_2 (Ss) bull 46, gave three self black animals. If these offspring are added to those above, a perfect 3:1 ratio is obtained (Table 6).

Four Ss bulls (Tables 8 and 9) used in 41 matings to self black hybrid cows of unknown composition (either SS or Ss), produced 31 self black and 10 white-spotted offspring.

Close agreement to expected proportions was obtained in eight Ss ♂ X ss ♀ matings (Table 4). Three were white-spotted and five self black, the expected proportion being 4:4. Likewise, four white-spotted and three self black were obtained in the backcross of ss males to Ss females (Table 7). If the two backcross matings are combined, the total offspring are 8 self black and 7 white-spotted, which is close to the expected 1:1 ratio. Similar matings, not included above (Tables 5 and 10), show 4 selfs and 6 white-spotted, making the combined result for all four sets of matings, 12 selfs and 13 white-spotted.

Table 8. Matings of F_1 (Ss) and F_2 (Ss) Bulls with Self (SS or Ss) Females (not F_1)

Sire	Dam	Offspring	Composition Ss	Composition ss
33 F_1 (Ss) Black	26 F_2 Black	♀ 43	S	
33 F_1 (Ss) Black	26 F_2 Black	♀ 63	S	
33 F_1 (Ss) Black	26 F_2 Black	♀ 71	S	
33 F_1 (Ss) Black	32 F_2 Black	♀ 51		ss
33 F_1 (Ss) Black	32 F_2 Black	♂ 60	S	
33 F_1 (Ss) Black	29 F_2 Black	♀ 61	S	
33 F_1 (Ss) Black	29 F_2 Black	♂ 70		ss
33 F_1 (Ss) Black	27 F_2 Black	♂ 53	S	
33 F_1 (Ss) Black	41 F_2 Black	♀ 67	S	
66 F_1 (Ss) Black	62 ($BcxF_1$) Black	♂ 89	S	
66 F_1 (Ss) Black	67 F_3 Black	♂ 92	S	
66 F_1 (Ss) Black	47 Bc Black	♀ 93		ss
66 F_1 (Ss) Black	44 F_2 Black	♀ 95	S	
46 F_2 (Ss) Black	41 Bc Black	♂ 79	S	
46 F_2 (Ss) Black	41 Bc Black	♀ 102	S	
46 F_2 (Ss) Black	43 F_3 Black	♀ 76	S	
46 F_2 (Ss) Black	43 F_3 Black	♀ 85	S	
46 F_2 (Ss) Black	63 F_3 Black	♀ 87		ss
46 F_2 (Ss) Black	67 F_3 Black	♀ 103		ss
46 F_2 (Ss) Black	80 F_3 Black	♀ 114		ss
69 F_2 (Ss) Black	76 F_{3-4} Black	♂ 96	S	
			15	6

Table 9. Matings of Self Black (Ss) F_2 Bulls with Self Black (SS or Ss) F_2 Cows

Sire F_2	Dam F_2	Offspring	Composition S	ss
46 (Ss) Black	26 Black	♀ 80	S	
46 (Ss) Black	29 Black	♂ 81		ss
46 (Ss) Black	29 Black	♀ 98		ss
46 (Ss) Black	42 Black	♀ 77	S	
46 (Ss) Black	42 Black	♀ 90	S	
46 (Ss) Black	42 Black	♂ 100	S	
46 (Ss) Black	42 Black	♀ 109	S	
46 (Ss) Black	44 Black	♀ 115	S	
46 (Ss) Black	45 Black	♀ 97	S	
46 (Ss) Black	45 Black	♂ 111	S	
46 (Ss) Black	48 Black	♂ 78	S	
46 (Ss) Black	62 Black	♀ 99	S	
46 (Ss) Black	62 Black	♂ 107	S	
46 (Ss) Black	65 Black	♀ (C)	S	
46 (Ss) Black	65 Black	♀ 110	S	
46 (Ss) Black	68 Black	♀ 101		ss
46 (Ss) Black	68 Black	♂ (D)	S	
69 (Ss) Black	44 Black	♂ 83	S	
69 (Ss) Black	44 Black	♂ 104	S	
69 (Ss) Black	65 Black	♀ 88		ss
			16	4

Table 10. Matings of F_1 Bull with ss Cows (not F_1)

Sire	Dam	Offspring	Composition Ss	ss
33 F_1 (Ss) Black	31 F_2(ss) Spotted	♂ 50	S	
33 F_1 (Ss) Black	31 F_2(ss) Spotted	♂ 57		ss
33 F_1 (Ss) Black	31 F_2(ss) Spotted	♂ 75		ss
33 F_1 (Ss) Black	34 Bc(ss) Spotted	♀ 62	S	
33 F_1 (Ss) Black	34 Bc(ss) Spotted	♀ 73	S	
33 F_1 (Ss) Black	36 Bc(ss) Spotted	♂ 64		ss
			3	3

Inheritance of Horns

The inheritance of horns in cattle has been the subject of considerable study by geneticists and animal breeders. The presence of a gene for horns and its allelomorph was early suggested by Bateson and Saunders (1902). Later, Spillman (1905) scouted the idea that the horned character of cattle was inherited in a mode conforming to Mendel's law. Gowen (1918) offered additional evidence from a controlled experiment, where the polled, beef type Aberdeen Angus was crossed with the horned, dairy types, Jersey, Holstein, Guernsey, and Ayrshire, showing in general that polledness is inherited as a simple dominant. Gowen's data show, however, that horns appeared in males of the F_1 generation at least once in each of the crosses of the Aberdeen Angus bull, Kayan, with Ayrshire, Jersey, and Guernsey cows.

Lloyd-Jones and Evvard (1916) cite two individuals out of 78 Shorthorn X Galloway crossbreds that developed horns. Lloyd-Jones and Evvard (page 98a) also refer to the work of Mossom Boyd, in which the F_1 polled Hereford bull, Wilson, mated to horned Hereford cows, gave the expected 1:1 ratio in the offspring, assuming the monohybrid interpretation to be correct. However, in the case of a second F_1 Hereford bull, Variation, with 28 progeny, 22 were listed as polled and six as horned, which hardly conforms to the 1:1 ratio since the deviation, 8 ± 1.78 is approximately 4.5 times its probable error.

In the Alaska Agricultural Experiment Station Galloway herd which numbered 368 head, a part of which were closely inbred, no scurs or horns are recorded over a period of 26 years. There is good reason for believing that purebred Galloways are seldom heterozygous for the horned condition. However, one cannot overlook the possibility of a horned breed carrying a specific sex-limited gene which, when present in the crossbred, causes the formation of scurs or abortive horns in spite of the polled gene (P). In fact, if a single factor hypothesis is retained in analyzing the work of investigators working with polled X West Highland, Ayrshire, and native African cows, the postulation of another modifying gene is necessary for even a theoretical acceptance of the results.

Watson (1921) records six F_1 polled females, one F_1 horned male, and one polled male (another stillborn horned animal is not included) from the breeding of seven horned West Highland cows, one horned West Highland X Chartley crossbred cow, and one horned Angus X Chartley crossbred cow with four polled Angus bulls.

Watson also states that, from observation, in crosses made in Dumfrieshire between Red Polls and Ayrshires, most of the F_1 males were horned. He cites Arkell's experiment (1912) with sheep, in which it is shown that the inheritance of horns in some breeds of sheep is sex-limited, as a possible explanation.

Smith (1927) cites two cases in which polled Angus bulls were crossed with native northern Rhodesia, Africa, cows. In the first case, Aberdeen Angus bull X native cows there were 27 F_1 females and 8 F_1 males completely polled and 15 F_1 males with distinct horns or buds. In the second case the exact number is not known, but:

"Practically all of the heifers were polled and practically all the males with buds, short dropping horns, or ordinary horns."

Cole (1924) states that the polled condition of the Aberdeen Angus persists in the Aberdeen Angus X Jersey crossbreds, and that in 15 Angus X Holstein crosses, no horns have appeared. This is in line with the findings at the Alaska Agricultural Experiment Stations of the Galloway X Holstein reciprocal crosses. Fifteen F_1 Holstein ♂ X Galloway ♀ hybrids, of which eight were males and seven were females, were polled (Table 2). Four of the male hybrids developed light scurs, but the bony structure of the heads gave no indication of bumps or abortive horns. The

Alaskan Holstein X Galloway F_1 bull, No. 7, grew small "button" scurs at one year of age which had not enlarged at two years of age when the bull was castrated and sold. There were 10 F_1 Galloway ♂ X Holstein ♀ hybrids, 5 males and 5 females, of which one, bull No. 6, grew scurs approximately one inch in diameter at ten months of age, which enlarged to approximately two inches in diameter at four years of age. Another F_1 bull of similar breeding, No. 66, grew small scurs, about one inch in diameter at two years of age. With one exception, no other scurs have appeared in the herd. The one exception, F_3 male 100, from the F_2 horned cow No. 42 and the extracted heterozygous F_2 polled bull 46, showed scurs approximately one inch in diameter at eighteen months of age. The F_1 bull 6 (with scurs) mated to nine F_1 cows sired three horned males and six polled females, while the F_1 bull 33 (no scurs) mated to F_1 cows produced ten F_2 males, of which three had horns, and six F_2 females of which one had horns. The F_1 bull 66 (scurs) mated to three F_1 cows had three female progeny, all of which were polled, (Table 3).

The F_2 generation consisted of 6 horned and 9 polled males, and 3 horned and 11 polled females, a total of 9 horned and 20 polled (Table 3), which is not significantly different from the theoretical ratio of 7.25:21.75.

Further evidence of the monohybrid behavior of the genes for polled and horned is shown in Table 11, which gives the results of the mating of three heterozygous polled bulls to six extracted homozygous horned cows. The offspring were three polled males, four polled females, six horned males, and five horned females, a ratio of seven polled to eleven horned for both sexes. If the offspring of the backcross of the F_1 cows to Holstein bulls (Table 12) are added to the above, the combined result would be 10 polled and 16 horned, as indicated below:

	Males		Females	
	Polled	Horned	Polled	Horned
Hybrid Pp ♂♂ X hybrid pp ♀♀ (Table 11)	3	6	4	5
Holstein pp ♂♂ X hybrid F_1 ♀♀ (Table 12)	2	2	1	3
Totals ----------------	5	8	5	8

The deviation from a perfect 1:1 ratio is three, and is not significant statistically. The results from the backcross can be explained very satisfactorily on a monohybrid basis. The production of three males with scurs in the F_1 generation, on the other hand, suggests, the additional presence of a sex-limited modifying gene. It seems necessary to postulate still another sex-limited gene to account for the horned F_1 males obtained by other workers.

Table 11. Mating of Heterozygous Polled (Pp) Males X Recessive (pp) Females

Sire			Dam		Offspring		
66HG	F_1	Polled	62HG	Horned	♂	89HG	Polled
66HG	F_1	Polled	67HG	Horned	♂	92HG	Horned
66HG	F_1	Polled	41HG	Horned	♀	93HG	Horned
46HG	F_2	Polled	42HG	Horned	♀	77HG	Horned
46HG	F_2	Polled	41HG	Horned	♂	79HG	Horned
46HG	F_2	Polled	42HG	Horned	♀	90HG	Polled
46HG	F_2	Polled	62HG	Horned	♀	99HG	Polled
46HG	F_2	Polled	42HG	Horned	♂	100HG	Polled
46HG	F_2	Polled	41HG	Horned	♀	102HG	Horned
46HG	F_2	Polled	67HG	Horned	♀	103HG	Horned
46HG	F_2	Polled	62HG	Horned	♂	107HG	Polled
46HG	F_2	Polled	42HG	Horned	♀	109HG	Polled
46HG	F_2	Polled	31HG	Horned	♀	116HG	Polled
33HG	F_1	Polled	31HG	Horned	♂	50HG	Horned
33HG	F_1	Polled	31HG	Horned	♂	57HG	Horned
33HG	F_1	Polled	36HG	Horned	♂	64HG	Horned
33HG	F_1	Polled	41HG	Horned	♀	67HG	Horned
33HG	F_1	Polled	31HG	Horned	♂	75HG	Horned

It has been shown that there is a one factor difference between self and white-spotting and between polled and horned. Dihybrid crosses involving both pairs of allelomorphs have been made. In the production of the F_1 double heterozygotes both of the dominant genes (S and P) came from the Galloway parent and the two recessives from the Holstein. The F_2 results were 10 self, polled, 5 self, horned, 4 white-spotted, polled, and 2 white-spotted, horned (Table 3). There were 21 F_2 animals, and the results obtained are sufficiently close to a 9:3::3:1 ratio to justify the assumption that we are dealing here with independent inheritance, and that therefore S and P are not linked.

Table 12. Backcross Matings of Hybrid F_1 Polled (Pp) Cows to Horned (pp) Holstein Bulls

Sire P1	Dam F1	Offspring
7H	3HG	♂ 9 HG Horned
7H	1HG	♂ 12 HG Horned
20H	21HG	♂ 35 HG Polled
20H	1HG	♂ 37 HG Polled
20H	18HG	♀ 34 HG Polled
20H	5GH	♀ 36 HG Horned
20H	16HG	♀ 38 HG Horned
20H	3HG	♀ 41 HG Horned

SUMMARY

1. By means of crosses between Galloways and Holsteins it has been demonstrated, through the descendants, that a number of individuals in the Galloway breed are heterozygous for recessive white-spotting (s). It has even been shown that among purebred Galloways a recessive white-spotted individual (ss) occasionally occurs.
2. The Holstein-Galloway crosses also brought out that the Galloways often carry pigmented leg (Pl), a dominant modifier of recessive white-spotting, and white-restriction (Wr), another dominant modifier, which causes a generalized reduction in the amount of white-spotting in ss animals.
3. Both parent breeds carry the dominant white-spotting gene In (inguinal white).
4. By means of the later generations in the above cross, it was demonstrated that the gene for self (S) and recessive white-spotting (s) form an allelomorphic pair.
5. Evidence is presented which indicates that susceptibility to extreme mammitis may be due to a dominant gene.

6. The genes for polled (P) and horned (p) form an allelomorphic pair, but there seems to be evidence from the above and other crosses that some horned individuals carry a dominant sex-limited gene which causes crossbred males to be horned in spite of the fact that they carry the gene for polled.

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PLATE I

Fig. 1. Holstein Bull 1H, Chimacum Sir Quirinus Cornucopia, Reg. No. 176468. This bull is believed to carry an intermediate amount of white-spotting (Lwlw).

Fig. 2. Holstein Bull 20H, Shadford Segis Hartog 2nd, Reg. No. 352564. No. 20H carries the least amount of white-spotting of any of the Holsteins used as parents of the F_1 hybrids. He is, therefore, assumed to be LwLw.

PLATE I

Fig. 1

Fig. 2

PLATE II

Fig. 3. Holstein Cow No. 4H, Miss Gladys Cornucopia, Reg. No. 336455. This cow is quite typical in the amount of black carried by most of the Holstein cows of the parent herd.

Fig. 4. Holstein Bull No. 35H, Heilo Pontiac King, Reg. No. 519811. Bull No. 35H was used only on some of the F_2 and F_3 cows, in tests for white-spotting. He is included here chiefly because he carries the amount of white-spotting found in typical Holsteins.

PLATE II

Fig. 3

Fig 4

PLATE III

Fig. 5. Holstein Cow No. 9H, Gladys Mercedes Banks 2nd, Reg. No. 596282. This cow in addition to carrying a preponderance of black pigment in the coat (LwLw) shows some black on the legs. This should not be confused with "pigmented leg" (Pl), which characteristically begins at the hoof and extends up the backs of the legs.

PLATE III

Fig. 5

PLATE IV

Fig. 6. Galloway Bull No. 303, Ranger of Seven Oaks, Reg. No. 45044. No. 303 carries only a few white hairs on the scrotum, but three out of his five offspring were white-spotted in five matings with Holstein cows (Table 2).

Fig. 7. Galloway Bull No. 329, Aberdeen, Canadian Reg. No. 2646. No. 329 carries an excessive amount of inguinal white. His offspring exhibited recessive white-spotting (s) in one Galloway and one Galloway-Yak mating.

PLATE IV

Fig. 6

Fig. 7

PLATE V

Fig. 8. Galloway Cow No. 215, Fidelia 6th of Kodiak, Reg. No. 41730. No. 215 is solid black, no white hairs present, as is usually the case in self colored animals.

Fig. 9. Galloway Cow No. 247, True Beauty 3rd of Kodiak, Reg. No. 45138. No. 247 carries a rather large amount of white and produced a white-spotted calf, ♂ 11, when bred to the registered Holstein bull 1H.

PLATE V

Fig. 8

Fig. 9

PLATE VI

Fig. 10. Galloway Cow No. 187, Fidelia 4th of Kodiak, Reg. No. 40335. No. 187 is the dam of F_1 ♀ No. 3, who has more than 30 direct descendents in the hybrid herd.

Fig. 11. Galloway Cow No. 246, Maggie of Kodiak, Reg. No. 45143. A typical Galloway matron in medium flesh.

Fig. 12. Galloway Cow No. 277, Jaynes Banshee, Reg. No. 48193. Dam of F_1 hybrid, ♀ No. 16, who shows a large amount of inguinal white.

Fig. 13. Galloway Cow No. 293, Miss of Red Cloud's Girl, Reg. No. 48148. A typical self black matron of the Galloway herd. Dam of the white-spotted F_1 hybrid, ♀ No. 18.

PLATE VI

Fig. 10

Fig. 11

Fig. 12

Fig. 13

PLATE VII

Fig. 14. F_1 Hybrid Bull No. 6 (Galloway bull 163 X Holstein cow 3H). A self black animal, with inguinal white. (Roughened appearance is due to defective film.)

Fig. 15. F_1 Hybrid Bull No. 33 (Holstein bull 1H X Galloway Cow 252). A self black animal with a small white spot on scrotum.

Fig. 16. F_1 Hybrid Cow No. 39 (Holstein bull 20H X Galloway Cow No. 246). A self black animal, except for the white on the udder.

PLATE VII

Fig. 14

Fig. 15

Fig. 16

PLATE VIII

Fig. 17. Self, F_1 Hybrid Bull No. 66 (Galloway bull 329 X Holstein cow 16H).

Fig. 18. Self, F_1 Hybrid Cow No. 16 (Holstein bull 1H X Galloway cow 277). Carries inguinal white.

Fig. 19. White-spotted, F_1 Cow No. 18 (Holstein bull 1H X Galloway cow 293). No. 18 shows slightly more white on left than on right side.

Fig. 20. White-spotted, F_1 Cow No. 14 (Galloway bull 303 X Holstein cow 6H). No. 14, in addition to having a white underline, switch, and tongue showed more or less white on each of the four feet.

Plate VIII

Fig. 17

Fig. 18

Fig. 19

Fig. 20

PLATE IX

Fig. 21. Self, F_2 Hybrid Bull No. 69 (F_1 bull 33 X F_1 cow 16). (No. 69 was suffering from a leg injury at time the picture was taken, from which he later recovered only to meet with disaster by falling in an abandoned mining shaft.)

Fig. 22. Self, F_2 Hybrid Cow No. 45 (F_1 bull 33 X F_1 cow 18).

Fig. 23. Self, F_2 Hybrid Cow No. 42 (F_1 bull 33 X F_1 cow 14).

Fig. 24. Self, F_2 Hybrid Bull No. 46 (F_1 bull 33 X F_1 cow 16). No. 46 weighed 2020 lbs. when the picture was taken, and is a sire of more than 30 of the later hybrids.

Fig. 25. Self red, F_2 Hybrid Female B (F_1 bull 46 X F_1 cow 39). Female B is the only red animal produced by either the Alaskan Galloway and Holstein purebred herds or their crossbred descendants. The total number of animals involved is over 500. The shade of red was a deep cherry with no white hairs in evidence on any part of the body. Both parents must have been heterozygous blacks (Bb).

PLATE IX

Fig. 21

Fig. 22

Fig. 23

Fig. 24

Fig. 25

PLATE X

Fig. 26. White-spotted, F_2 Hybrid Cow No. 94 (F_1 bull 66 X F_1 cow 16). No. 94 carries a relatively large amount of white-spotting for a hybrid.

Fig. 27. White-spotted, F_2 Hybrid Cow No. 82 (F_1 bull 66 X F_1 cow 16). No. 82 and No. 94 above are full sisters. No. 82, however, carries the pigmented leg gene, <u>Pl</u>, while No. 94 does not.

Fig. 28. White-spotted, F_2 Hybrid Cow No. 31 (F_1 bull 6 X F_1 cow 3). No. 31 is a good example of a white-spotted (<u>ss</u>) animal carrying plus modifiers reducing the amount of white. In addition to the white udder, she had a white tongue and switch.

Fig. 29. White-spotted, F_2 Hybrid Male No. 74 (F_1 bull 33 X F_1 cow 14). No. 74 shows a comparatively large amount of white-spotting. His genetic composition probably is <u>ss</u>, <u>lwlw</u> (or <u>Lwlw</u>), <u>WrWr</u>, <u>plpl</u> (see page 13).

PLATE X

Fig. 26

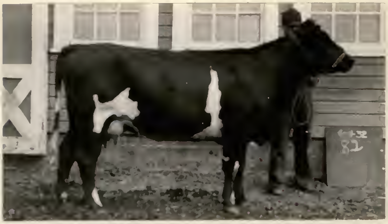

Fig. 27

Fig. 28

Fig. 29

PLATE XI

Fig. 30. White-spotted, F_3 Hybrid Cow No. 88 (F_2 bull 69 X F_2 cow 65). No. 88 carries the dominant pigmented leg gene, Pl.

Fig. 31. White-spotted, F_3 Hybrid Male No. 105 (F_2 bull 46 X F_2 cow 82). The dam of 105 is No. 82 (fig. 27). Since she is pigmented legged (Pl) and he is not, evidence is thus furnished that she must be heterozygous (Plpl).

Fig. 32. White-spotted, Backcross Male No. 35 (Holstein bull 20H X F_1 hybrid cow 21).

Fig. 33. White-spotted, Backcross Female No. 36 (Holstein bull 20H X F_1 hybrid cow 5). No. 36 shows the pigmented leg character. It seems probable that she also carries Wr.

Fig. 34. White-spotted Backcross male No. 12 (Holstein bull 7H X F_1 hybrid cow 1). No. 12 shows white-spotting of an odd design. To some extent the pigmented and the white areas have been interchanged. He is pigmented legged (Pl).

PLATE XI

Fig. 30

Fig. 31

Fig. 32

Fig. 33

Fig. 34

Fig. 30

Fig. 31

Fig. 32

Fig. 33

Fig. 34