Genetical Studies in the Clydesdale Breed

by

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Doctor of Philosophy.

Prince of Albion (6178)

Photograph of Statuette in Bronze in the possession of Sir John Gilmour

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Part I.

The Clydesdale Breed.

INTRODUCTION.

BREED HISTORY.

That the effect of environment is no less potent in the development of a breed than it is in that of an individual is clearly exemplified by the history of the Clydesdale breed of horses. The alternations of war and peace have had the greatest effect on the breeding of stock in general and on the horse in particular. The importance of the horse in early agriculture and in war rendered this doubly so. Unfortunately these conditions of state affairs have need of different standards so that the horse which would carry a knight in armour was not necessarily the best for more pastoral pursuits. Due to this lack of uniformity of standards and lack of time to devote to breeding, the development of the horse in the direction of agricultural utility was extremely slow - even to the end of the 17th century. About this time, owing to the abatement of war and the expansion of the coalfields in the Lanarkshire region, there came a change for the better in the closely linked pursuit of agriculture. This period, therefore, may be taken as having given rise to the Clydesdale breed, of a type differing greatly from that of to-day.

It is widely held that the Clydesdale

Breed originated in the progeny of a cross between Flemish Stallions imported by the sixth Duke of Hamilton and some of the best Lanarkshire mares about 1750.

Selection of the progeny of an English Stallion Blaze and mares belonging to Paterson of Lochlyoch is claimed to play an important part. The "Lampits mare", of direct descent from the Lochlyoch stock, is credited with having been the dam of Glancer (335), whose son Glancer II (336) was the sire of Broomfield Champion (95). The most famous son of the last mentioned was Clyde (153) who left much valuable stock. His seven sons, Prince of Wales (155), Farmer (290), Farmers Fancy (298), Muircock (550), Prince Charlie (625), Prince Royal (647) and Baasay(21), were in the opinion of McNeilage all important in the West of Scotland. The belief that the Lampits mare was the dam of Glancer (335) is, however, questioned by McNeilage (1908), who alleges that sufficient attention had not been paid to dates in the deducing of the evidence in connection therewith. There is much controversy on the subject of the origin of the Clydesdale breed: Consensus of opinion, however, points to its having originated in the result of crossing some imported stallions of high merit with the leading mares in Lanarkshire.

The first organised period in breed history

commences with the foundation of the Clydesdale Horse Breeding Society in 1877. Interesting as the fields of speculation may be, the orderly records of the Stud Book are to be preferred for purposes of genetic analysis. It is to this part of the breed history that special attention is paid in this work.

There is a two-fold value in a study of a breed of domesticated livestock based upon an analysis of the amount of inbreeding which has occurred in it. The percentage of homozygosity is a result of inbreeding. Such an analysis therefore delineates to a great extent the history of the breed, the more so if an analysis of the pedigrees apart from inbreeding is also made. This information is not merely useful as regards the breed itself, but is of value for comparison with other breeds.

The second principal function of such an analysis is the provision of an index of normality with which can be compared the exceptional animals of the breed. In this way, information may be obtained firstly concerning whether certain characteristics appear to be of genetic origin. If this be the case then it is possible to trace the animals in the breed responsible for the transmission of such characters.

The purpose of the present study is mainly to investigate the second point especially the inheritance of prizewinning ability, and of certain

defects. Before this can be done, it is essential to establish the normality of the breed. The work of Calder (1927) has been used as the basis for normality. His figures have been brought up to date by the inclusion of 49 stallions and 35 mares selected at random from the animals born in the five-year period 1925-30. As in Calder's paper Sewall Wright's Coefficient of Inbreeding has again been used, this being the only Coefficient measuring the homozygosity which results from inbreeding.

According to Wright, inbreeding can only be considered to occur when a common ancestor appears in the pedigree of both the sire and the dam of the individual considered. Unless this were so, an absurd situation would arise which might be exemplified from a cross between the Aberdeen Angus and the Shorthorn. Both the parent breeds are appreciably inbred and possess a considerable number of common ancestors particular to each breed. By any other system than Wright's Coefficient of Inbreeding which requires the common ancestor to appear on both sides of the pedigree, the first cross of the Aberdeen Angus and Shorthorn would have to be considered as an inbred animal, which is absurd.

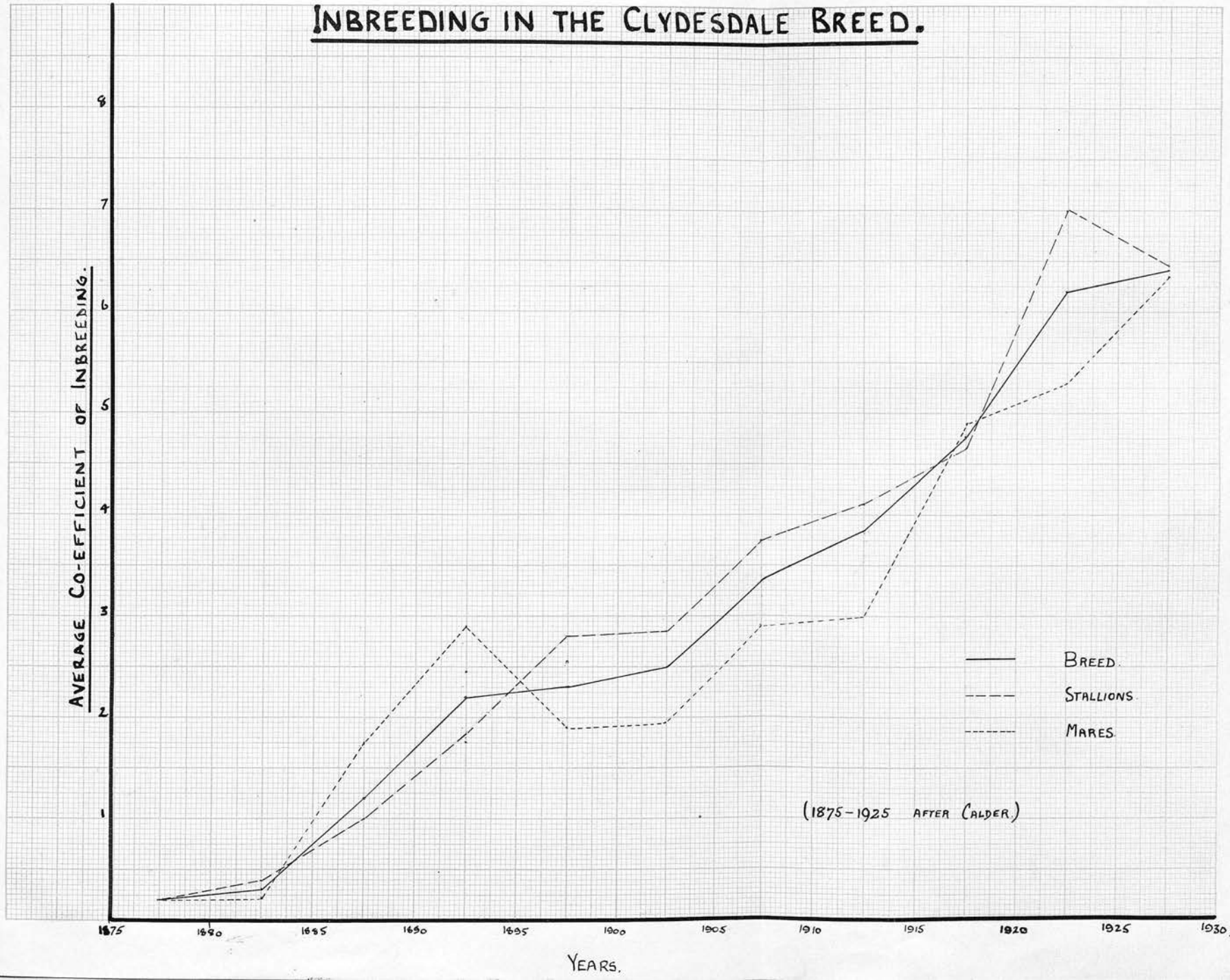
Method. The development of the Clydesdale Breed has been already studied by Calder. In analysing the role of inbreeding in the growth of this breed, he

made use of the official stud book. This has been continued, but with a slight deviation in the method of making the random sample for the last five-year period. The method of sampling adopted by Calder consisted in taking the stallions entered at the top of every fifth page in every fifth volume, finishing with both volume 47 and 48. Upon examination of the material subsequent to volume 48, it was found that the above method was not applicable, owing to the paucity of stallions foaled between 1925 and 1929 registered in the Stud Books. Accordingly, the stallions at the tops of three pages out of every four in each volume were taken. Such a method gave 49 stallions foaled between 1925 and 1929.

A new method of sampling for mares had also to be evolved. It was finally decided to take every fifth mare registered as having been foaled after 1925 and appearing in Stud Books Nos. 49, 50, 51 and 52. Such a method gave 35 mares for inclusion in the period 1925 and 1929.

These pedigrees were tabulated. The average coefficient of inbreeding for mares, stallions and the breed in general for 1925 to 1929 was calculated. Compared with the previous trend in the breed, these results show a slight decrease in the average coefficient of inbreeding for the stallions, a distinct increase in that for mares, and a slight increase in the breed as a whole. This is illustrated

GRAPH I


INBREEDING IN THE CLYDESDALE BREED.
AVERAGE CO-EFFICIENT OF INBREEDING.
8
7
6
5
4
3
2
1
1875
1880
1885
1890
1895
1900
1905
1910
1915
1920
1925
1930
YEARS.
BREED.
STALLIONS.
MARES.
(1875-1925 AFTER CALDER.)

by graph on page 6.

It is not intended to review in detail the whole history of the breed as analysed by this method since Calder has already done so.

Since the time of inception of the Clydesdale Breed until about 1890, breeding practice had involved several lines of descent of which no single one was especially favoured. Thereafter, in the first decade of this century, it became apparent that there were two main lines of descent - from Darnley (222), and Prince of Wales (673). Both of these stallions were outstanding, but the progeny of the latter did not confirm so closely to type as those of the former. The descendants of Prince of Wales had good substance and were of good draught type. These points were probably due in no small measure to the Shire blood in the pedigree of their foundation sire. The Darnley line, however, has predominated and has given the breed a succession of pre-eminently successful sires. Topgallant (1850), the son of Darnley, was the sire of Sir Everard, who sired Baron's Pride (9122). There has been more inbreeding to the last mentioned sire than to any other in the Clydesdale Breed. The distinct rise during the ten-year period from 1915-1925 was due to the concentration of the blood of Baron's Pride through his son, Baron of Buchlyvie, and through the son of

TABLE I (CALDER). ¥

Analysis of Inbreeding to Prominent Sires in the Clydesdale Breed.

No. of Five-Year Period.	"Prince of Wales" (1865)			"Darnley" (1872)			"Top-Gallant" (1877)			"Macgregor" (1878)			"Sir Everard" (1885)			"Baron's Pride" (1890)			"Baron of Buchlyvie" (1900)		
	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
4	.	.	.	10	4.37	0.43	2	3.12	.06	.	.	.	1	6.25	.08	8	7.64	0.59	.	.	.
5	4	1.72	.07	27	3.67	0.99	4	3.38	.12	2	1.95	.05	11	3.56	.31	30	4.76	1.46	38	4.72	1.82
6	23	2.79	.63	44	1.95	0.87	11	0.65	.03	4	1.76	.07	42	1.65	.68	67	4.09	2.73			
7	43	1.61	.69	78	1.38	1.07	50	0.68	.34	10	.35	.04	79	1.09	.86	85	2.51	2.12			
8	48	1.64	.78	86	1.39	1.18	70	0.54	.37	18	.62	.11	88	0.87	.77						
9	89	0.80	.72	92	1.08	0.98	97	0.74	.71	39	.37	.14									
10	92	0.78	.72	100	1.03	1.03	100	0.40	.40	14	.34	.05									
11	100	0.62	.62	100	0.98	0.98															
12	100	0.56	.56																		

N.B.- For each stallion, column (a) gives the percentage of animals inbred to him during each five-year period.
" " " " (b) gives the average percentage of inbreeding to him.
" " " " (c) gives the average percentage of inbreeding to him in each sample of the population considered.

¥ "The Rôle of inbreeding in the development of the Clydesdale Breed of Horses"-Page 126

the latter, Dunure Footprint. The general curve of inbreeding would seem to indicate that breeders are now considering the possibility of an outcross to this line. Whether or not the line of inbreeding will, in the future, rise, depends upon the ancestry of the next prepotent sire who makes as great an improvement in the breed as the three sires previously noted made in their day and generation. If such a sire be of the Baron of Buchlyvie, Footprint line, the curve of inbreeding may again be expected to rise sharply. There still exist a few animals tracing in comparative purity through Hiawatha to the foundation sire Prince of Wales and these are being largely used on the inbred mares. Should the prepotent horse occur from such a mating, the coefficient will remain about the same and then rise as inbreeding takes place to this sire. The situation will then be analogous to that which occurred in the Shorthorn breed following the use of Champion of England as referred to by Wright (1925).

More important from the breed point of view is the part played by the different stallions in its construction. Calder published a table similar to Table I showing the amount of inbreeding which had taken place to those stallions to which appreciable inbreeding had occurred. The stallions were grouped in five-year periods, the percentage of the breed

TABLE II.

A Comparison of Inbreeding to prominent sires during periods 1925-29 and 1920-25.

Name of Stallion and Date of Birth.	No. of 5-Year Period after Birth.	A.			B.			C.		
		This Study.	* Preced. Period.	Incr. or Decr.	This Study.	* Preced. Period.	Incr. or Decr.	This Study.	* Preced. Period.	Incr. or Decr.
Prince of Wales. (1866)	13	100	100	0	.60	.56	+.04	.60	.56	+.04
Darnley. (1872)	12	99	100	-1	.82	.98	-.16	.81	.98	-.17
Topgallant (1877)	11	89	100	-11	.19	.40	-.21	.17	.40	-.23
Macgregor. (1878)	11	52	14	+38	.23	.34	-.11	.12	.05	+.07
Sir Everard (1885)	9	32	88	-56	.44	.87	-.43	.14	.77	-.63
Baron's Pride (1890)	8	81	85	-4	1.32	2.51	-1.19	1.07	2.12	-1.05
Hiawatha (1892)	8	19			1.22			.13		
Montrave Mac. (1893)	8	23			.59			.14		
Baron of Buchlyvie (1900)	6	48	38	+10	3.23	4.72	-1.49	1.54	1.82	-.28
Auchenflower (1902)	6	17			2.76			.46		
Dunure Footprint (1908)	4	12			6.61			.79		

Where for each Stallion:

A.... gives the percentage of animals inbred to him in five-year period.

B.... gives the average percentage of inbreeding for animals inbred to him in five-year period.

C.... gives the average percentage of inbreeding to him in sample of population considered.

*.....gives in these columns figures taken from Calder (1927).

inbred to them was shown as well as the degree of inbreeding in the animals inbred and the degree of inbreeding in the breed as a whole. This table has now been extended and includes the younger stallions Auchenflower, born 1902 and Dunure Footprint, born 1908. Two other older stallions, not included by Calder, have also been added, namely Hiawatha, born 1892 and Montrave Mac, born 1893. To both of these, some slight degree of inbreeding occurred before the period under analysis in this paper. The fact that, in Table II, inbreeding is only shown to have occurred in respect of these two stallions at 40-50 years after their birth does not imply that cases did not occur sooner.

Results.

An analysis of the parts played by the leading stallions mentioned is Table I and II reveals the following facts. After a small decrease from period II to period 12, the average percentage of inbreeding to Prince of Wales increases from .56 to .60 which last closely approximates to the corresponding figure for period 11 which was .62. Owing to the fact that one individual in the class sample had no inbreeding to Darnley, the percentage of animals, in period 12 inbred to Darnley, appears as 99. Apart from this, both the average percentage of inbreeding among animals inbred to Darnley and the average percentage of inbreeding to Darnley in the

sample of the population considered, show a decrease, the former from .98 to .82 and the latter from .98 to .81.

In the case of Topgallant, there is a decrease in all three figures considered, the percentage of animals inbred to him decreasing from 100 to 89, the average percentage of inbreeding among animals inbred to him from .40 to .19. Owing to the decrease in the percentage of animals inbred to Topgallant the fall in the average percentage of inbreeding to him in the sample of population considered appears as being from .40% to .17%. A somewhat similar decrease in this respect was seen in the case of Sir Everard and Baron's Pride. The increase or decrease with regard to the preceding period is given for all three figures for each individual horse in Table II.

CONCLUSION :

(a) The history of the Clydesdale Breed during the period 1925-1929 has been studied and the inbreeding practised during that time has been calculated.

(b) There is a depression in the amount of inbreeding to the Darnley-Topgallant -Sir Everard-Baron's Pride line. The Darnley line through Macgregor does not show this depression.

In general, it may be assumed that there is a temporary tendency towards outcrossing during 1925-1930, not through any one particular prepotent sire but a tendency which is rather incremental in nature.

Part II.

Prizewinning Stallions.

INTRODUCTION.

The term, "Like begets Like", on occasion calls for some modification. As a rule this may be accepted as being a close approximation to the actual state of affairs, but exceptions to it are sufficiently numerous to warrant a closer examination.

One such exception is referred to by Anderson (1920), who mentions the thoroughbred, "Peter the Great". This stallion, who was not specially distinguished phenotypically, and from his pedigree apparently no more so genotypically, "has been regarded by most, not only as the most successful sire of his breed, but also as the greatest sire of all breeds". It obviously requires more than a casual examination of the pedigree of such animals to reveal the cause of their unusual qualities.

The randon appearance of certain individuals in a pedigree does not provide the solution to the problem. Frequently, it would seem that ancestors are of less importance individually than when they are in combination with other ancestors.

It is rather unlikely that such combinations are merely the result of chance, but it is likely that some common influence is at work in their production. Such an influence is probably

the conscious or unconscious selection practised by the leading breeders. If such is the case, then it is necessary to have some measure of this influence. Such a measure can only be applied indirectly and the method of so doing lies not so much in the estimation of the amount of inbreeding practised among the animals under consideration, but in the close analysis of their pedigrees and of the parts played by leading ancestors in the production of the various types studied, especially in the relation of any one such ancestor to the others.

MATERIAL.

Material from which data suitable for an investigation such as this might be drawn would have to satisfy the following requirements:-

In the first place, it would have to be as representative as possible, secondly, it would have to signify a uniformly high standard of merit and thirdly, it would be desirable to have data extending over as long a period as possible.

Such requirements are well fulfilled by the merit list of the Glasgow Stallion Show, whose three-year-old stallion class has been used.

This Show had its origin in a hiring fair

and has been in existence since about 1889. The stallions shown at it have always been considered to be the leaders of the breed, the more so as the Show is held in the heart of the Clydesdale country. Judgments in the foal and two-year-old class are often subsequently reversed. Such an eventuality, however, is much more rare in the case of the three-year-old where the merit of the animals entered is more readily apparent than in the more immature stages. The use of the three-year-old class also enables results to be more speedily brought up to date.

Records of the first six stallions in this class were available with few breaks from 1890 onwards. Owing to a few irregularities of occurrence in the early days of the Show, there were several departures from the procedure adopted subsequently. The first show is in 1879 and some older stallions were included. In 1884 eleven stallions were considered. Six stallions were used in 1889, 1890 and 1891. Five were considered in 1894. Starting in 1895 and omitting the years 1896 and 1900-1902 inclusive, six stallions have been made use of for each show until 1931.

Pedigrees of the stallions up to 1927 had been tabulated at the Department of Animal Genetics. These records were then extended by the present writer to include 1931. The total number of

prizewinning stallions considered for whom the coefficient of inbreeding was worked out amounted to 249.

METHOD.

In order to facilitate the study of pedigrees in this work, a system of filing cards was used. A card was allotted to each year covered by the study. On the face of each such card, were the following particulars:-

(a) The names of stallions in order of merit.

(b) The coefficient of inbreeding of each stallion.

(c) The average coefficient of inbreeding of stallions.

Information regarding the method of breeding and a full analysis of the inbreeding of each stallion was arranged on the reverse side of each card.

An outline sketch of the arrangement of material is given on page 17.

Copy of Specimen Card.

Face.

YEAR OF SHOW 1923

PLACE	NAME	NO	COEFFICIENT OF INBREEDING
1	FLASHDALE	20576	10·679
2	PRINCE CHARMING	20534	9·113
3	BUCHAN VOUCHER	20519	5·893
4	CRAGSTON MOUNT ROYAL	20721	6·916
5	EDDLEWOOD MAINLINE	20568	12·403
6	DUNMORE HIAWATHA	20740	3·553
	AVERAGE COEFFICIENT OF INBREEDING		8·093

Reverse.

PLACE	BREEDING. SIRE.	DAM.	DETAILS OF INBREEDING TO DIFFERENT SIRES. T	B.P.	B.O.B.	M.M.	MAC.	D.	P.
1	DUN. FOOTPRINT.	BY BARON'S PRIDE.		6·488		1·563		·967	·195
2	BY BARON O. BUCH.	BY DUN. FOOTPRINT.	·585		6·538			·909	·981
3	BY BARON O. BUCH.	BY BARON'S VOUCHER.	·195	3·244				1·414	·842
4	DUN. FOOTPRINT.	BY SCOTLAND YET	·683	4·866				1·078	·189
5	DUN. FOOTPRINT	BY THE DUNURE	·340		9·807		·195	·705	·249
6	HIAWATHA AGAIN	BY BONNY BUCH.						1·014	2·539

Key to symbols used.

T- Topgallant (1850)
D.- Darnley(222)
P.- Prince of Wales(673)
B.P- Baron's Pride(9122)
B.o. B.-Baron of Buchlyvie(11263)
M.M.- Montrave Mac.(9958)
Mac.- Macgregor(1487)

TABLE III.

INBREEDING of PRIZEWINNERS.

Period.	No. of Stallions.	Average Coefficient of Inbreeding.			
		All Prizewinners.	First Two Prizewinners.	Last Two Prizewinners.	Stallions in the Breed. *
1875-79	5	.818	-	-	.21
1880-84	11	.470	-	-	.37
1885-89	18	.698	1.255	.568	.97
1890-94	17	4.247	5.383	3.309	1.70
1895-99	12	4.357	5.883	5.255	2.70
1900-04	32	2.885	3.429	2.058	2.80
1905-09	33	4.311	4.381	3.738	3.70
1910-14	33	4.684	5.053	3.966	4.10
1915-19	31	5.010	5.308	4.473	4.70
1920-24	30	7.421	7.748	6.024	7.00
1925-28	24	6.830	7.872	5.825	6.46

* Figures taken from paper by Calder (1927).

RESULTS:

In order that inbreeding amongst prizewinners might be readily compared with the same system of mating among stallions in the breed, the prize-winning stallions were arranged in five-year periods according to the date of birth in Table III.

These periods corresponded to those used by Calder and the results of the prizewinners are compared with those of the breed as a whole by the graph on the following page.

Inspection of the Table and Graph shows:-

(1) that the line expressing the average coefficient of inbreeding among all prize-winners lies approximately midway between those representing average coefficient of inbreeding in first two stallions and the average coefficient of inbreeding among stallions in the Clydesdale Breed,

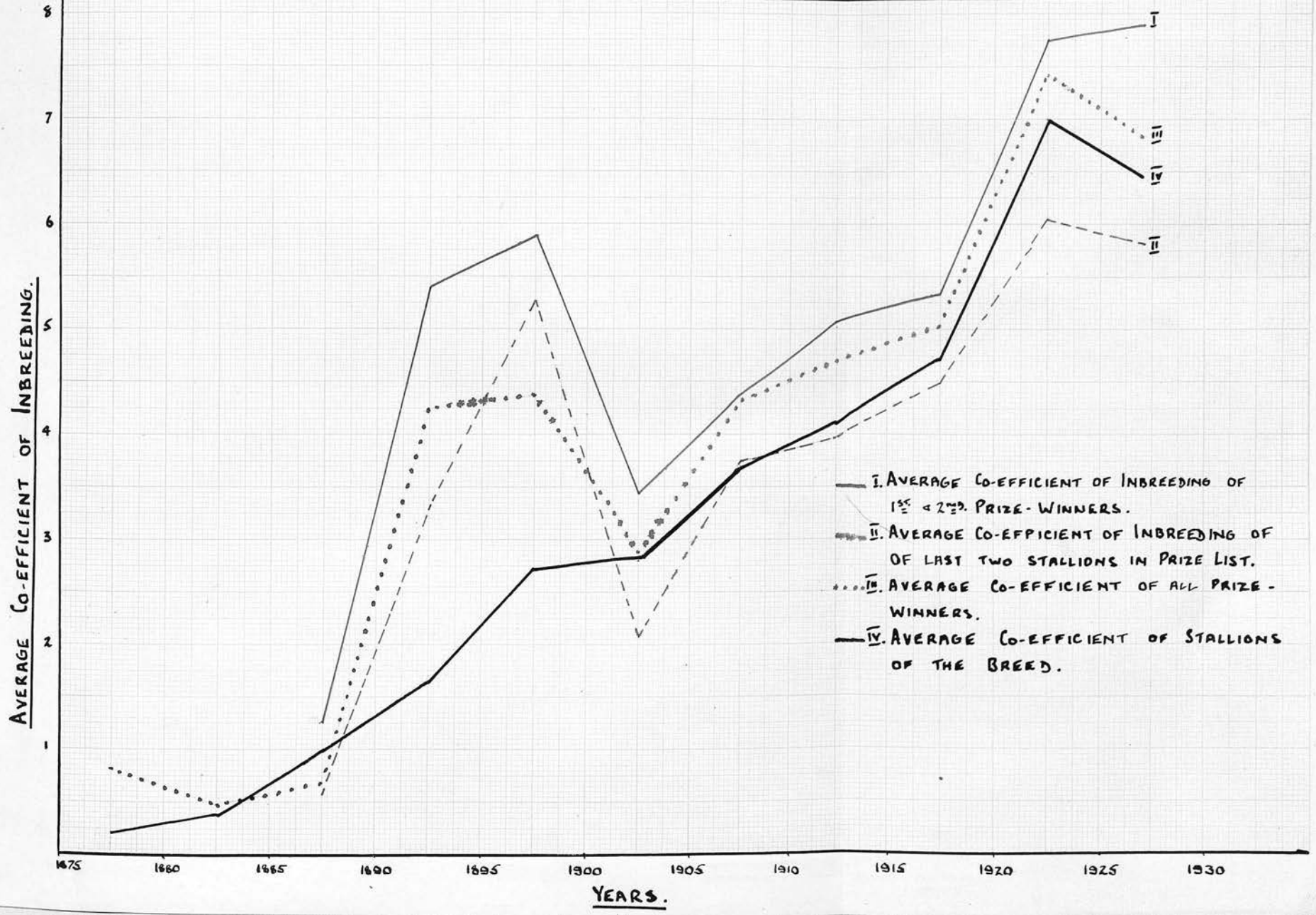
(2) that the average coefficient of inbreeding of the stallions placed first and second in the merit list is definitely greater than the average percentage of inbreeding among stallions in the breed during corresponding periods.

(3) that the average coefficient of inbreeding among stallions placed fifth and sixth in the merit list approximates most closely

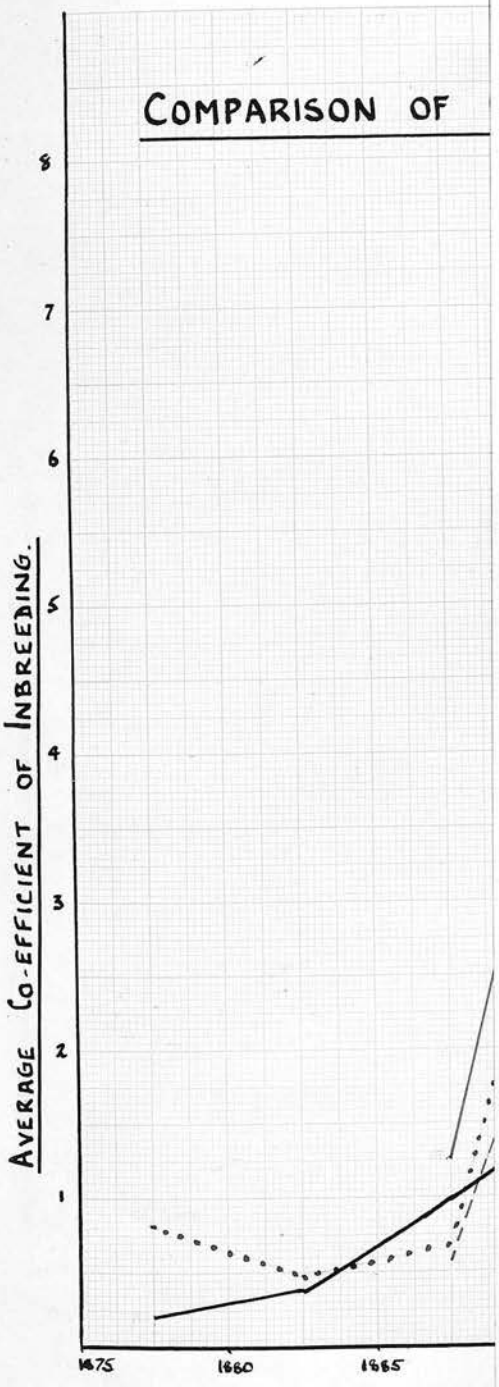
GRAPH 2

INBREEDING.

COMPARISON OF CLYDESDALE PRIZE-WINNERS AND BREED STALLIONS.



GRAPH 2


COMPARISON OF
AVERAGE CO-EFFICIENT OF INBREEDING.
8
7
6
5
4
3
2
1
1675
1680
1685

to the average coefficient of inbreeding among stallions in the breed.

In order to ascertain the cause of these differences, it was essential to make a closer examination of the pedigrees.

Accordingly, making use of the five-year periods employed in the previous tables, the average coefficient of inbreeding to prominent sires was calculated for each of these. This was carried out for:-

(a) Stallions placed first and second.
(b) Stallions placed fifth and sixth.
(c) All Prizewinning Stallions.

The results of these analyses are contained in Tables IV, V, and VI, and from a consideration of data contained in Table IV, the following facts regarding the relationship between inbreeding in prizewinners and in the breed during corresponding periods were noted.

In order that the degree of inbreeding to various sires in the breed might be readily ascertained, a table VII to show the dates corresponding to the periods reckoned in groups of five years after the birth of each sire, was drawn up. This was deemed necessary as periods among prizewinners are estimated in five-year groups from 1890 onwards,

while those in the breed are calculated from the date of birth of each sire considered.

Contributions to Inbreeding:

The primary part of the increase in inbreeding among the prizewinning stallions is directly attributable to inbreeding to "Darnley's" sons, "Topgallant" (1850), and "Macgregor" (1487). In this respect, the inbreeding among prizewinners resembles that of the breed stallions; thereafter, towards 1914, there occurs a notable difference. Amongst breed stallions, the increase in the coefficient of inbreeding is augmented materially by contributions to "Sir Everard" (5353), "Topgallant" and to a lesser extent to "Macgregor", while the increase in inbreeding among prizewinners is due primarily to the earlier introduction of inbreeding to "Baron's Pride" (9122).

Amongst prizewinning stallions during this time, contributions due to inbreeding to "Sir Everard", "Topgallant" and "Macgregor" actually decrease. Such a decrease in the contribution made to the total inbreeding through these three stallions continues, and the net increase is maintained by an increase in contributions to "Baron's Pride". From 1910 to 1920, this increase is augmented by contributions to "Hiawatha" and "Baron of Buchlyvie" - such contributions being of a minor nature. After 1920, the

Key to Symbols used in Tables IV, V and VI.

A.	"Auchenflower" (12007).
B.B.	"Baron of Buchlyvie"(11263).
B.P.	"Baron's Pride" (9122).
D.	"Darnley" (222).
D.F.	"Dunure Footprint"(15203).
H.	"Hiawatha" (10067).
M.	"Macgregor" (1487).
M.R.	"Mount Royal" (8065).
P.	"Prince of Wales" (673).
R.F.	"Royal Favourite" (10630).
S.E.	"Sir Everard" (5353).
T.G.	"Topgallant" (1850).

TABLE IV.

"FIRST TWO" PRIZEWINNERS.

Analysis of Inbreeding.

Date of Birth of Stallions.	Average Coefficient of Inbreeding to:-										
	P.	D.	T.	SE.	M.	BP.	BB.	H.	RF.	A.	DF.
1890-94	.61	.31									
1895-99	1.06	.87									
1900-04	1.73	.84	.16								
1905-09	.96	1.15	.81	.47	.20						
1910-14	.41	.88	.18		.06	2.26					
1915-19	.45	1.23	.36	.23	.04	1.09					
1920-24	.67	1.10	.26	.37	.36	1.66	2.37				
1925-28	.51	.59	.08	.26	.22	1.93	1.76	.24	.07	.10	1.81.

TABLE V.

"LAST TWO" PRIZEWINNERS.

Analysis of Inbreeding.

Date of Birth of Stallions.	Average Coefficient of Inbreeding to:-										
	P.	D.	T.	SE.	M.	BB.	BP.	M.R.	H.	DF.	A.
1890-94	.17	.16									
1895-99	1.56	.31									
1900-04	1.08	.77									
1905-09	1.65	.63	.33	.31							
1910-14	1.09	1.46	.18	.16	.02	.65					
1915-19	.60	.70	.29	.22	.17	.65	1.64	.06			
1920-24	.72	.75	.22	.18	.08	1.31	1.36		.04	.64	
1925-28	.54	.67	.15	.08	.08	1.36	.63		.42	.40	.48

TABLE VI.

ALL PRIZEWINNERS.

Analysis of Inbreeding.

Date of Birth of Stallions.	P.	D.	Average Coefficient of Inbreeding to:- T.	S.E.	M.	B.P.	H.	B.B.	R.F.	D.F.
1890-94	1.14	.46								
1895-99	2.93	1.59								
1900-04	1.27	.97								
1905-09	1.08	.77	.29	.26	.06					
1910-14	1.15	1.06	.22	.18	.03	1.24	.19	.19		
1915-19	.65	.93	.24	.15	.03	1.58	.15	.21		
1920-24	.59	.94	.28	.20	.15	1.60	.14	1.82	.03	.64
1925-28	.56	.68	.11	.18	.10	1.19	.35	2.25	.02	.73

TABLE VII.

PERIODS of LEADING SIRES.

No. of Period.	"Darnley" (1872)	"Prince of Wales" (1866)	"Topgallant" (1877)	"Baron's Pride" (1890)	"Sir Everard" (1885)	"Macgregor" (1878)	No. of Period.
1.	1872-76	1866-70	1877-81	1890-94	1885-89	1878-82	1.
2.	1877-81	1871-75	1882-86	1895-99	1890-94	1883-87	2.
3.	1882-86	1876-80	1887-91	1900-04	1895-99	1888-92	3.
4.	1887-91	1881-85	1892-96	1905-09	1900-04	1893-97	4.
5.	1892-96	1886-90	1897-01	1910-14	1905-09	1898-02	5.
6.	1897-01	1891-95	1902-06	1915-19	1910-14	1903-07	6.
7.	1902-06	1896-00	1907-11	1920-24	1915-19	1908-12	7.
8.	1907-11	1901-05	1912-16	1925-29	1920-24	1913-17	8.
9.	1912-16	1906-10	1917-21		1925-29	1918-22	9.
10.	1917-21	1911-15	1922-26			1923-29	10.
11.	1922-26	1916-20	1927-31				11.
12.	1927-31	1921-25					12.
13.		1926-30					13.

proportion of the inbreeding attributable to "Baron's Pride" decreases slightly.

During 1910-1914, the average coefficient of inbreeding to "Baron of Buchlyvie" was .19, while corresponding figures for periods 1915-1919 and 1920-1924 were respectively .21 and 1.82.

Thus, the increase in inbreeding, which in the breed stallions was attributable almost wholly to contributions to "Baron's Pride" was maintained among prizewinners by the earlier introduction of contributions to "Baron of Buchlyvie".

The earlier introduction of inbreeding to "Dunure Footprint", which took place in 1927 and 1929, maintained the difference in intensity of inbreeding between prizewinning stallions and the breed in general during period 1925-1929.

Comparison of Inbreeding among Prizewinners.

In order to avoid repetition, the stallions placed first and second and those placed fifth and sixth, have been respectively denoted by the letters A and B.

The lines expressing the amount of inbreeding in the Classes A and B and the average of prizewinners, are necessarily influenced in their variation by two factors.

(a) The coefficients of inbreeding to prominent sires.

(b) The times of appearance of inbreeding to those sires.

Examination of Table IV reveals the fact that the sire to whom the major share of inbreeding takes place in the A Class is "Baron's Pride". "Darnley" is next in importance and is closely followed by "Prince of Wales". "Baron of Buchlyvie" from 1920-1924 is responsible for quite a large share of inbreeding.

The distribution of inbreeding in the B Class shows several significant differences from the proportions noted above. Firstly, the sum of contributions due to "Baron's Pride" is much less, being almost the same as that due to "Baron of Buchlyvie" in the A Class. Secondly, the contributionsto "Baron of Buchlyvie" is increased; and thirdly, while "Darnley" was responsible for a greater amount of inbreeding than "Prince of Wales" in the A Class, it is seen that in the B Class, the position is reversed. Contributions due to inbreeding of "Topgallant" and "Sir Everard" are also less than corresponding contributions in the A Class.

The main difference therefore in the amount of inbreeding which exists between the A Class and the B Class is due to the decrease in inbreeding to "Baron's Pride" in the latter, the amount of

inbreeding to him being almost halved when compared with the A Class. Sires of the "Darnley-Topgallant-Sir Everard-Baron's Pride"-line are all responsible for the lesser degree of inbreeding in the B Class.

From an examination of the coefficients of inbreeding, it is seen that there is a greater degree of inbreeding to "Prince of Wales" in the B Class than there is in the A Class, the amount of inbreeding to this sire being actually greater than that to "Darnley" in the former class.

Times of Occurrence of Inbreeding to Various Sires.

In connection with the relative amounts of inbreeding to sires, it is important to note the times at which contributions to these sires appear. Accordingly, these are shown in Table VIII.
Ten Stallions are included in Table VIII. To six of these, inbreeding occurs in the A Class before it occurs in the B Class. Inbreeding to "Hiawatha" is apparent at the same time in both classes.
Inbreeding to "Prince of Wales", "Baron of Buchlyvie" and to "Dunure Footprint" takes place earlier in the B Class than in the A Class.

TABLE VIII.

TIMES of OCCURRENCE of INBREEDING to PROMINENT SIRES.

Class.	Darnley (222)	Prince of Wales (673)	Topgallant (1850)	Sir Everard (5353)	Macgregor (1487)	Baron's Pride. (9122)	Baron of Buchlyvie (11,263)	Hiawatha (10,067)	Dunure Footprint (15,203)	Auchanflower (12,007)
A.	1895	1895	1907	1909	1912	1914	1923	1925	1929	1926
B.	1897	1890	1908	1912	1916	1918	1916	1925	1927	1929

The Part Played by Prominent Sires.

Prior to 1903, the paternal side of most of the pedigrees of prizewinners contained a large amount of "Prince of Wales" blood. The next stallion to figure prominently on the paternal side of these pedigrees was "Baron's Pride" (9,122). About the year 1905, "Hiawatha" (10,067) and "Marcellus"(11,110) replaced "Baron's Pride" and in turn gave way to stallions by "Baron of Buchlyvie" (11,263) and "Royal Chattan" (11,489). There is a further reversion to the use of "Prince of Wales" sires and in 1915, the first placed three-year-old was by "Apukwa" (14,567).

Thereafter is seen an attempt to combine the two strains, the usual method being to use "Baron of Buchlyvie" and "Dunure Footprint"(15203) on mares by "Hiawatha". Results of such combinations were prominent in the prize list of the 1916 Show. Temporary reversion to a higher concentration of "Darnley" blood is seen in the stallions figuring in the prize list of 1923 when sires by "Baron of Buchlyvie" were used upon "Footprint" mares.

From 1926 onwards, a further combination of the two lines occurs, with the following differences. In the previous combination, there was "Darnley" blood on the male side and "Prince of Wales" blood on the female side whilst the present

combination is effected by the use of such stallions as "Fyvie Enterprise" (20,581) and "Dunmore Hiawatha" (20,740) upon "Footprint" mares. At present, the use of "Benefactor" combines the two strains.

Relative Success of Sires and Progeny.

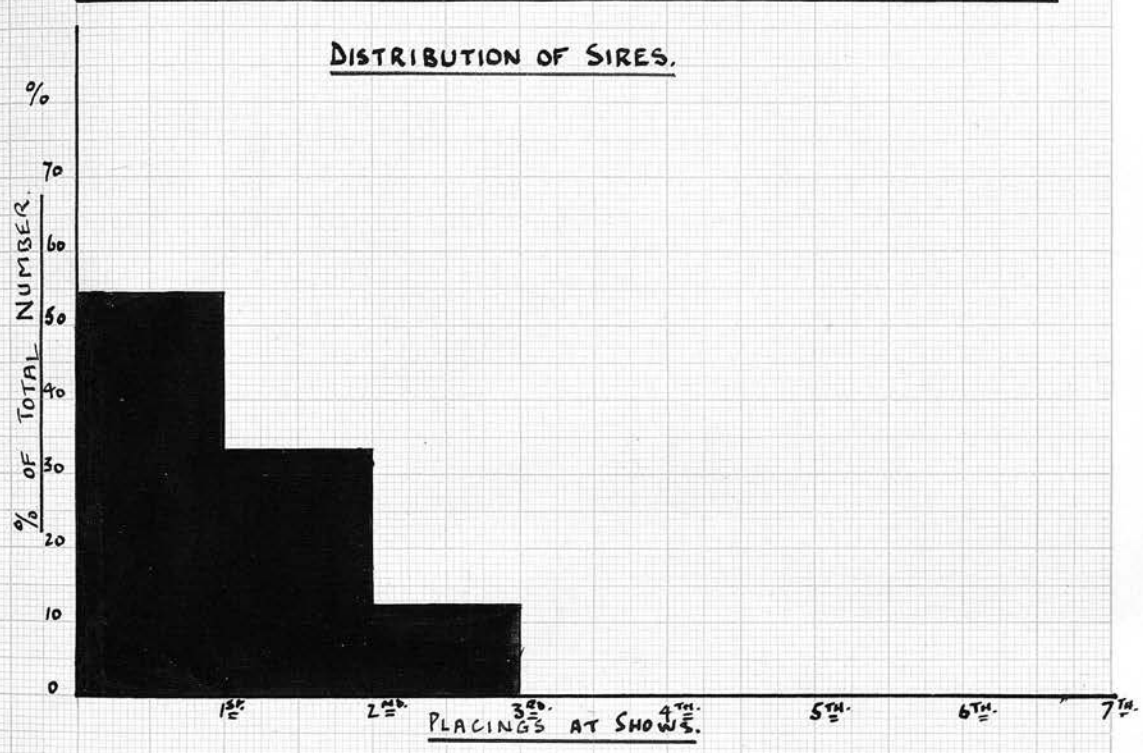
In order to make an estimate of the extent to which previous winners featured in subsequent winners' pedigrees, the following analysis was made. A table was drawn up in which was noted the year and place gained by an animal together with the year and place of his sire if the latter featured in the prize list. This showed that 25% of the prizewinners had sires who had previously figured in the prize list of the show class considered. The distributions of this 25% of stallions were then considered. All seven places were represented, ranging from 18 in the first place to 5 in the sixth. As regards the sires of these stallions there was a notable difference. These were found only in the first three places, and of these, the majority were found to have taken the first prize. The results are illustrated by graph on page 33.

DIAGRAM I

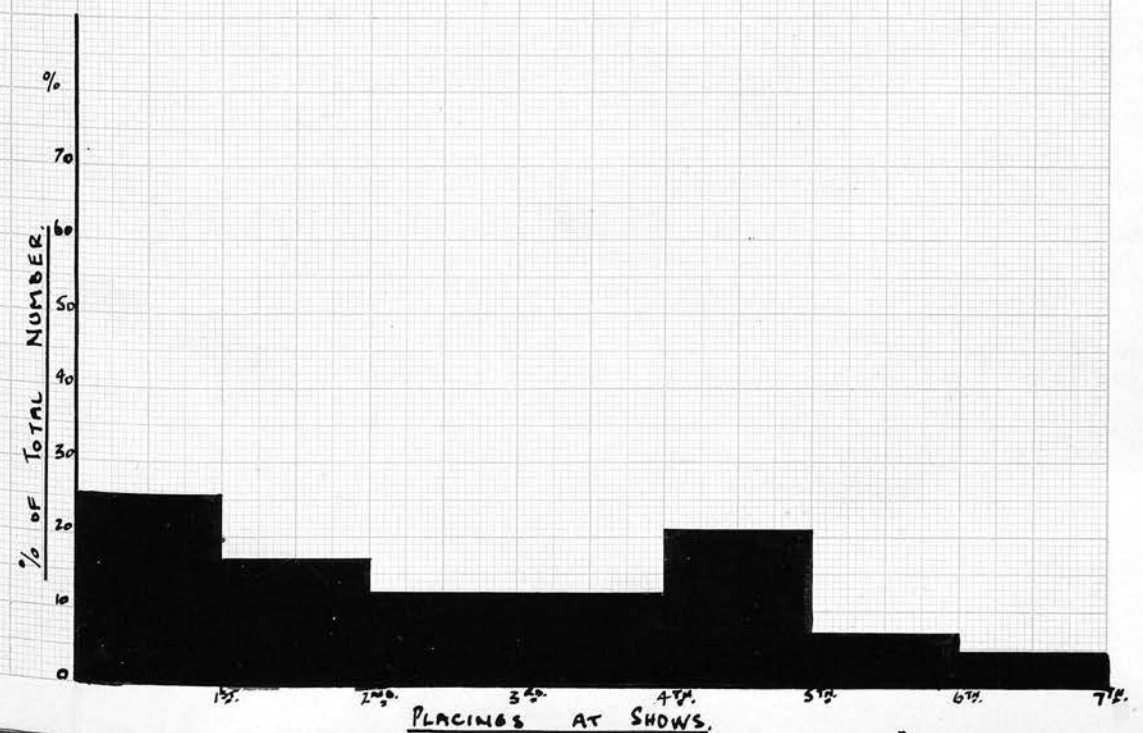
SHOW PLACINGS.

PERCENTAGE DISTRIBUTION OF SIRES AND PROGENY.

DISTRIBUTION OF SIRES.



DISTRIBUTION OF PROGENY.



From the foregoing, it will be noted that there is a rigorous selection of sires although the resulting progeny are necessarily distributed unevenly, so far as placing is concerned. Although the immediate parental generation only has been considered, a perusal of both the more distant generations on the paternal and maternal sides of pedigrees distinctly shows the large part which previous prizewinners have played in the ancestry of subsequent winners.

CONCLUSION.

The part played by inbreeding amongst Prizewinners has been considered. Stallions of superior merit show a higher degree of inbreeding than is to be found in the breed generally during the same period of time. This difference in inbreeding also exists between Prizewinners of high merit and Prizewinners of lesser merit.

A consideration of the breeding practised amongst Prizewinners has shown that there was -

(a) A period of alternation between the Prince of Wales by Darnley 1890-1915 and two combinations of the Darnley and Prince of Wales lines before and after 1923.

(b) The breeding of "First Two" and "Last Two" Prizewinners differs mainly by reason of the fact that the latter class have shown a greater degree of outcrossing to the Prince of Wales line than the former.

Inbreeding amongst Prizewinners is more advanced than in the Breed generally in two senses.

(a) Inbreeding to a particular group of sires takes place earlier amongst the

"First Two" Prizewinners than it does to the same group amongst the "Last Two" Prizewinners.

(b) Inbreeding amongst "First Two" Prizewinners is more intense than that practised amongst the "Last Two" Prizewinners.

Part III.

Defective Stallions.

NOTE.

The original data for this section have been chiefly obtained from the Department of Agriculture for Scotland and from the Ministry of Agriculture for England. The names are those of stallions refused licences under the Horse Breeding Act (1918). This information is strictly confidential and has only been provided on the understanding that the names of the defective stallions ,or any common line of breeding will not be divulged.

Introduction.

It has for long been considered by practical horse breeders that certain defects commonly met with are of an hereditary nature. This opinion has also been widely held by the veterinary profession. In 1888, with a view to furnishing evidence before The Royal Commission on Horse Breeding, the Council of the Royal College of Veterinary Surgeons communicated with members of the profession resident in Great Britain. As a result the council announced themselves as being of the opinion that certain diseases should be deemed a legitimate reason for disqualification for stud purposes. Sixteen diseases were so enumerated, of which number five would only disqualify under certain circumstances. Amongst those defects which disqualified under any circumstances were Ringbone, Sidebone, Bone Spavin, Roaring, Whistling and Shivering. Included in the group of defects deemed to justify rejection under certain circumstances was Stringhalt.

There are two methods of conducting an investigation into the problem of the inheritance of defects in the horse. Specially planned experiments may be carried out, or a study of reliable records may be made. Owing to the length of time required and the great cost/

cost of the first method greater use has been made of the second method, which has been employed in the present study. Data necessary for an adequate study are difficult to obtain but certain reliable records of defective horses, to which further reference will be made, were placed at the disposal of the Institute of Animal Genetics.

In an attempt to ascertain whether a defect in the human is or is not caused by a recessive hereditary factor Lenz (1919) has indicated the importance of noting the frequency of consanguineous unions among the parents of affected persons. "If a particular recessive morbific heredity factor existed in a masked form in one family only, the mating of two persons both harbouring the appropriate heredity factor could only occur through the marriage of near kin, so that exclusively in this way could the character become manifest: thus, in this extreme case the carriers of the character would all i.e. 100% be the offspring of consanguineous marriages. Further, if a recessive heredity factor is widely diffused throughout a population two such hereditary factors will of course often coincide without consanguineous marriage and the frequency of such marriage among the parents of persons suffering from the defect will be proportionately smaller." As an example Lenz takes the/

the case of blue eyes.

He observes, however, that recessive morbific factors will never be so widely diffused throughout the population as recessive factors for characteristics such as blue eyes.

To illustrate the importance of noting the degree of consanguinity he takes the case of 107 children born deaf, of whom 42 (or about 40%) were the offspring of marriages of near kin, the incidence of such marriage in the population at large being less than 1%. He concludes that "The rarer the character, being studied, is in the general population the more often may one expect to find that persons who exhibit the character are the offspring of marriages of near kin".

It is proposed to apply somewhat similar principles to the present study. In order to calculate the degree of inbreeding amongst defective horses the coefficient evolved by Wright has been used. An explanation of the application of this coefficient has already been given in Part I of this Thesis.

Material.

The Horse Breeding Act which was passed in 1918 is a measure which is designed to raise the standard of horse breeding in Great Britain by preventing the use of sires suffering from certain defects largely held/

held by the veterinary profession to be hereditary in nature. According to the terms of the Act, "Any person who at any time after the first day of January nineteen hundred and twenty, being the owner or having the control of a stallion which, for the purposes of these regulations, is deemed to have attained the age of two years, travels the stallion for service, or exhibits it in any premises not in his occupation with a view to its use for service, or permits it to be so travelled or exhibited, shall be liable, on summary conviction, to a fine not exceeding twenty pounds sterling unless the stallion is at the time licensed under the Act".

Defects which disqualify a stallion from being so licensed are - Cataract, Roaring, Whistling, High or Low Ringbone, Sidebone, Bone Spavin, Navicular Disease, Shivering, Stringhalt, Defective Genital Organs and Defective Conformation. The names of stallions for which licences have been refused and the reasons for refusal have been supplied confidentially by The Department of Agriculture for Scotland and The Ministry of Agriculture of England to The Institute of Animal Genetics where the pedigrees have been tabulated in respect of those refused licences on the grounds of one or more of the following - Ringbone, Sidebone, Bone Spavin, Shivering, Stringhalt, Roaring and Whistling.

Method.

The method of investigation consisted of a comparison of the amount of inbreeding amongst defective stallions with that of stallions in the Breed during the same period of time together with an analysis of the differences of breeding as revealed by an examination of the individual pedigrees.

The method of arrangement of data in the paper by Calder, which has been brought up to date in Part I of this Thesis, has already been described. For stallions in the Breed, the average coefficients of inbreeding were given for each of the five-year periods according to dates of foaling. These coefficients of inbreeding for stallions in the Breed as calculated by Calder and the present writer have been used as a basis of comparison.

For each defect the stallions were grouped together in five-year periods coinciding with those used for Stallions in the Breed and the mean coefficients of inbreeding for each group were calculated. Such figures however could not be fairly compared with mean coefficients of inbreeding of stallions in the breed during the same time, for the following reasons.

Firstly, as the Horse Breeding Act did not come into force until 1920 the classes 1900-1905 and 1905-1910/

1910 are wholly made up of a small number of aged stallions. In fact the data for only one defect - Ringbone - commenced in 1900. Of the remaining defects, the first cases of Roaring and Whistling occurred in the 1905-10 class, while the first cases of Side Bone, Bone Spavin, Stringhalt and Shivering occurred in the 1910-15 class. Secondly, with few exceptions, the number of cases in even the late classes was smaller than the number of cases used in the calculation of inbreeding amongst stallions.

It was proposed, therefore, to make the following fairer comparison of the average figures. The average percentage of inbreeding amongst all the cases of stallions suffering from any defect, as for example, Roaring, could be readily calculated. Cases of Roaring, according to date of birth, were to be found from 1900 to 1929. In order to derive a comparable figure for stallions in the breed it was necessary to assume that the number of stallions in the breed in each of the five year periods from 1900 to 1929 was equal. Such being almost the case a very close approximation to the mean coefficient of inbreeding of stallions in the breed during the 29 years, 1900 to 1929, was obtained by summating and averaging/

averaging their mean coefficients of inbreeding during each of the six periods from 1900 to 1929. This figure has been estimated for each defect, the mean figure for breed stallions varying according to the total interval of time over which the data for the particular defect extends. A table showing the average coefficients of inbreeding of stallions suffering from the various defects and the manner in which they differ from the corresponding figures for stallions in the breed during the same time is given on page 47.

For each defect the Standard Error of the mean coefficient of inbreeding has been calculated. In order to interpret the significance of these figures it was necessary to calculate the Standard Error of the difference between the mean coefficient for each group of defectives and the corresponding mean coefficient for Stallions in the breed. In the absence of the individual coefficients used by Calder (1927) in the calculation of the mean coefficient of inbreeding of stallions in the breed during the five year periods, the following course was adopted.

The Standard Error of the difference of two means is given by the equation -

$$S = \sqrt{s_1^2 + s_2^2}$$

Where S is the Standard Error of the difference/

difference of two means, the Standard Errors of which are, respectively, s_1 and s_2.

Let s_1 be the Standard Error of a mean coefficient in the case of the breed, and let s_2 be the Standard Error of the corresponding mean coefficient in the case of a defective group.

In view of the larger numbers of animals dealt with by Calder, it is reasonable to assume that the Standard Errors of the means estimated by him were less than one half of the corresponding Standard Error in the present study. Symbolically this may be written $2s_1 < s_2$. Returning to the equation it is seen that in cases where either s_1 or s_2 is much greater than the remaining term (a condition such as occurs here) the expression assumes the following form -

$$S = \sqrt{s_2^2} = s_2$$

The Standard Error of the difference between the two means may therefore be taken as being equal to the Standard Error of the mean coefficient of inbreeding in the case of the defective group.

The existence of a difference between the mean coefficient of inbreeding of a group of Defective Stallions and the mean coefficient of inbreeding of stallions in the Breed equal to twice the Standard Error has been taken as significant.

Results.

The mean coefficients of inbreeding of stallions suffering from the various defects, together with the corresponding mean coefficients of inbreeding of stallions in the breed, are given in Table IX. The difference between these two means, together with its standard error, is given in the case of each defect.

A study of the figures in the Table shows that the level of inbreeding amongst defective stallions is on the whole higher than that of stallions in the breed. In view of the findings in Part II it may be suggested that, as stallions for which licences are sought presumably constitute a selected portion of the stallion population, they will in all probability show a greater intensity of inbreeding than the stallion population at large. It must be noted, however, that the difference of inbreeding shown between defective stallions and stallions in the breed is by no means uniform, varying as it does, from + 1.11 $\pm$ .41 in the case of Stringhalt to -.45 $\pm$ .56 in the case of Shivering. Further, the existence of different degrees of inbreeding amongst stallions suffering from the different defects would seem to suggest that heredity plays at least some part in the transmission of some of these defects.

It is however, impossible to draw any conclusions from/

from a study of the above figures, which only assume their real significance when compared with corresponding figures for the breed. They can only be fully interpreted when considered in conjunction with the results of analysis of individual pedigrees compared with the results of similar analyses of pedigrees in the breed. For this reason, more detailed analyses of pedigrees of stallions suffering from the different defects have been made, and the results are discussed in the following section. A short account of the nature of each defect is also given.

TABLE IX.

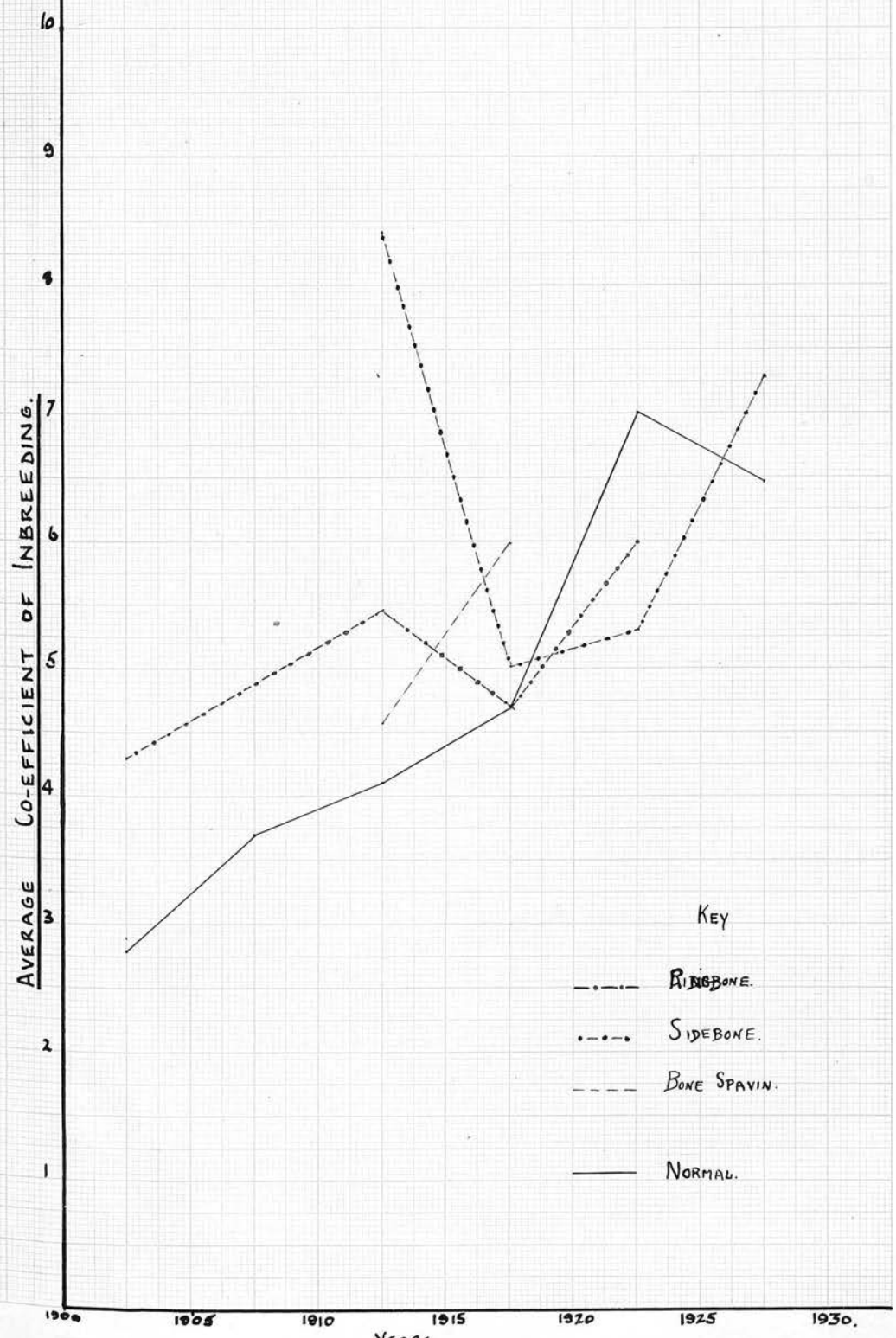
Coefficient of Inbreeding of Defective Stallions and their Comparison with the Average.

Defect	No. of Cases	Period over which data extends	Average Coefficient of Inbreeding of Stallions		Diff. in Coeffs. of Inbreeding
			Defective	In Breed	
Ringbone	18	1900-24	5.21	4.65	.56 ± .58
Sidebone	44	1910-29	6.04	5.57	.47 ± .56
Bone Spavin	10	1910-19	5.70	4.40	1.3 ± .72
Roaring	64	1905-29	5.59	5.19	.40 ± .36
Shivering	17	1910-29	5.12	5.57	.45 ± .56
Whistling	12	1905-24	6.59	4.88	1.71 ± .87
Stringhalt	50	1910-29	6.68	5.57	1.11 ± .41

GRAPH 3

INBREEDING OF DEFECTIVE AND NORMAL STALLIONS.

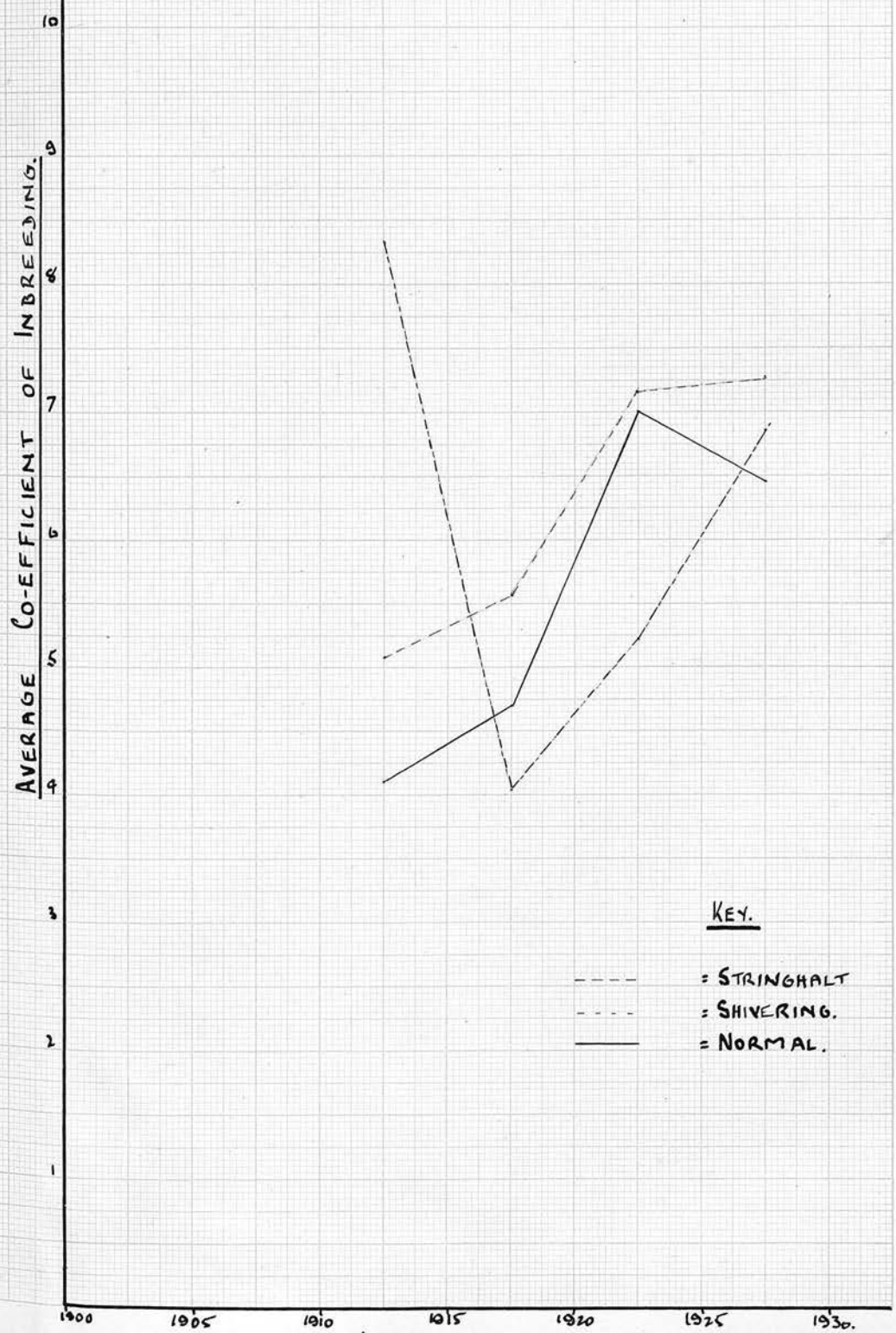
I. DEFECTS SHOWN ARE RINGBONE, SIDEBONE AND BONE SPAVIN.



GRAPH 4

INBREEDING OF DEFECTIVE AND NORMAL STALLIONS.

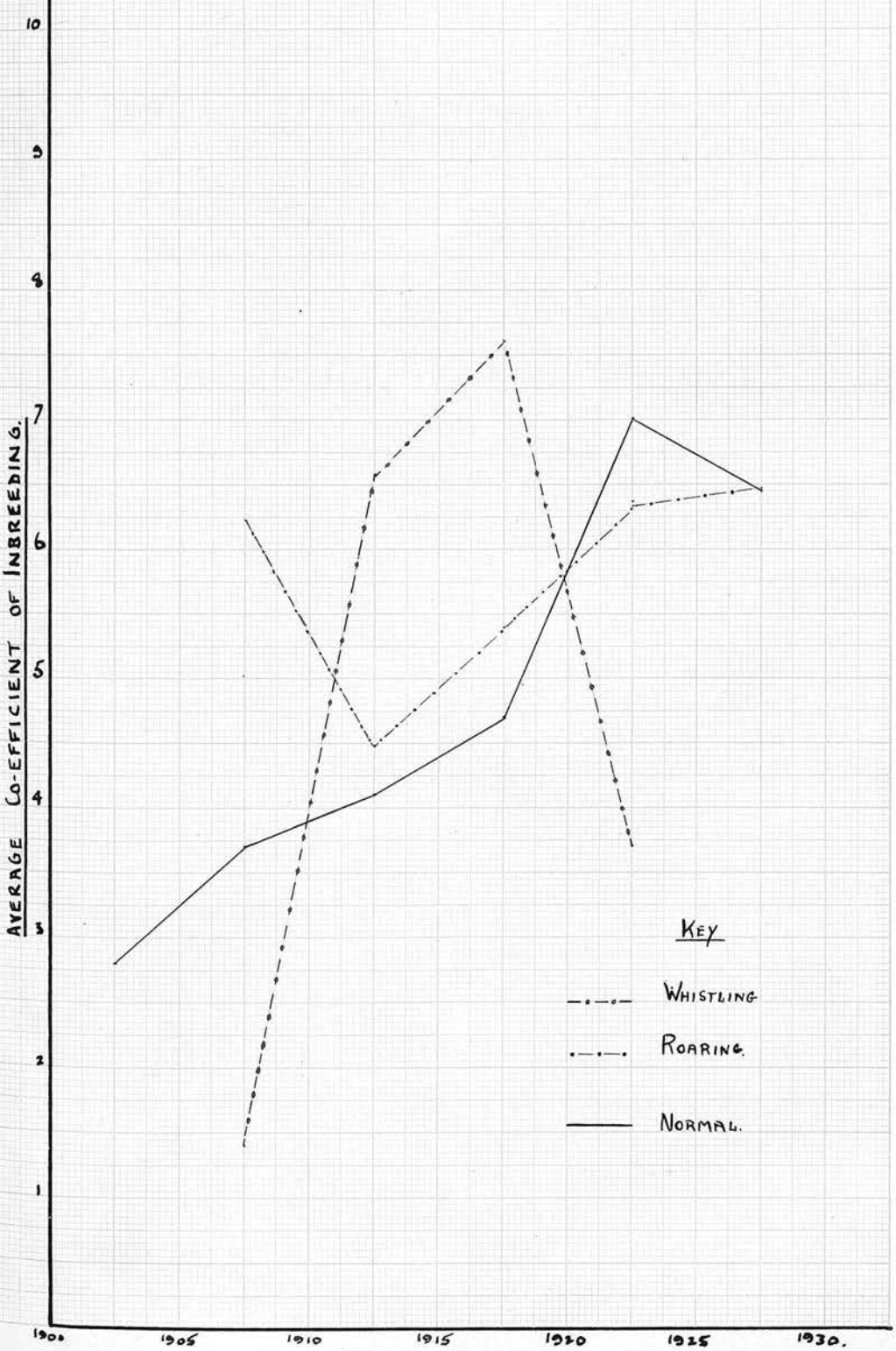
1. DEFECTS SHOWN ARE STRINGHALT AND SHIVERING.



GRAPH 5

INBREEDING OF DEFECTIVE AND NORMAL STALLIONS.

III. DEFECTS SHOWN ARE WHISTLING AND ROARING.



Ringbone and Sidebone.

Of defects in draught horses, Ringbone and Sidebone are probably the most frequently occurring, and it is proposed to treat them together.

Ringbone is a term applied to a bony exostosis affecting the interphalangeal joints of the foot of the horse. There are three forms of the defect - High Ringbone where the pastern joint is the seat of the disease, Low Ringbone in which the coffin joint is involved, and False Ringbone where the boney enlargement occurs upon the shaft of one of the bones and does not involve a joint. Externally, the condition may be recognised by reason of an alteration in the outline of the hoof, due to the fact that the extensor or pyramidal process of the coffin bone is usually affected. Its presence, especially when a joint has become ankylosed, causes a stilted action.

The term Sidebone is used to denote ossification of the lateral cartileges of the foot. Natural in the aged horse, it is however regarded seriously in the young horse, since its occurrence indicates a dangerous tendency towards abnormal bone formation in the foot of the animal.

Previous investigations into the hereditary nature of these defects have been made by Cameron (1916) and Robertson (1928). Cameron made an analysis/

analysis of the breeding of certain families of draft horses examined by him under his scheme of registration of stallions, which was introduced into Victoria in 1907. His study was largely based upon examinations of the paternal side of the pedigrees, but he realised the importance of an examination of the maternal side also. In reviewing his results he says "It is unfortunate that the records in most cases have reference to only the paternal side of the breeding of the individual horses examined, for there is no reason to believe that the hereditary influence of the dam is other than equally important as that of the sire. Indeed, the conclusion is irresistibly forced that, in the case of some of the families dealt with, the number of unsound descendants recorded would have been much greater but for the preponderating influence of "Sound" blood on the dams' side".

Robertson (1928) has made a further analysis of the data resulting from the same scheme. Like Cameron, he has shown that the defect is more prominent in some families than in others. He has also demonstrated the influence of dams by unsound sires on sound families, and has estimated the percentage incidence of the defects amongst the sons of certain stallions. In the largest family considered/

TABLE X

Analysis of Inbreeding amongst Stallions suffering from Ringbone.

Period according to year of Birth	No. of Cases	Average Coefficient of Inbreeding amongst stallions	
		Defective	in Breed
1900-04	1	4.30	2.80
1910-14	4	5.46	4.10
1915-19	8	4.69	4.70
1920-24	5	6.04	7.00
1900-24	18	5.21 ± .58	4.65

Difference between the average coefficient of inbreeding of Stallions suffering from Ringbone and the average coefficient of inbreeding of Stallions in the Breed during the period 1900-24;

.56 ± .58

considered he found that 10% of the members suffered from Sidebone. This, he showed, was almost wholly due to the presence, on the maternal side of the pedigrees, of certain individuals belonging to strains in which the abnormal occurrence of Sidebone had previously been demonstrated.

It is significant to note that both of these investigators have shown that the incidence of Ringbone and Sidebone varies in different families, which variation would seem to suggest that heredity plays some part in the transmission of these defects.

In the present investigation only eighteen cases of Ringbone were available for examination. The difference between coefficient of inbreeding and that of stallions in the breed was not significant, being .57 ± .58. Pedigrees of stallions possessed of Ringbone were examined and compared with those of stallions in the breed during the same time without any difference in either breeding practice or inbreeding to prominent sires being observed.

Cases of Sidebone were more numerous, there being forty-four, but when compared with the breed the difference in the mean coefficient of inbreeding was not significant, being .47 ± .56. The pedigrees of stallions in the 1910-1914 class closely resembled those of the breed both as regards breeding practice and/

Table XI

Analysis of Inbreeding amongst Stallions suffering from Sidebone.

Period according to year of Birth	No. of Cases	Average Coefficient of Inbreeding amongst stallions	
		Defective	in Breed.
1910-14	11	8.43	4.10
1915-19	24	5.07	4.70
1920-24	7	5.27	7.00
1925-29	2	7.35	6.46
1910-29	44	6.04±.56	5.57

Difference between the average coefficient of inbreeding of stallions suffering from Sidebone and the average coefficient of inbreeding of Stallions in the breed during the period 1910-29;

.47±.56

TABLE XII.

ANALYSIS of INBREEDING amongst STALLIONS suffering from SIDEBONE, 1915-1919.

Class.	Col.	B.P.	S.E.	T.G.	P.	D.
Defective Stallions.	(a)	55	36	82	100	91
Breed.	(a)	30	42	50-70	89-92	86-92
Defective Stallions.	(b)	4.95	.98	.72	.61	1.51
Breed.	(b)	4.76	1.65	.68-.54	.80-.78	1.39-1.08
Defective Stallions	(c)	2.69	.36	.59	.61	1.38
Breed.	(c)	1.46	.68	.34-.37	.72	1.18-.98

and inbreeding. Many of the stallions in this class, however, for which licences were refused in the early years of examination under the Horse Breeding Act 1918, would probably be Sideboned as a result of age. This process of ageing would not be expected to exert so great an influence on stallions foaled between 1915 and 1919 and it is significant to note that their pedigrees differ in several respects from those of stallions in the breed during the same period of time. In group 1915-1919 there are twenty four cases out of a total of forty-four. Results of an examination of the pedigrees in this group are given in Table XII, and from this it is seen that the defective stallions showed more inbreeding to Baron's Pride, Topgallant and Darnley as compared with the Breed.

Pedigrees of eleven stallions foaled between 1920 and 1929 did not exhibit any measurable difference from those of stallions in the breed.

From comparison with stallions in the breed it would appear that some difference between the breeding of stallions suffering from Ringbone and of those suffering from Sidebone does exist, but due to lack of numbers the evidence upon Ringbone is unfortunately rather inconclusive. Taking into consideration, however, the question of the occurrence of Sidebone with/

with age, the class 1915-1919 which is also largest numerically, seems to give results of some significance. From these it would appear as though the defect Sidebone is hereditary in nature and that its transmission is in some way intimately connected with inbreeding to the Baron's Pride line of descent.

Bone Spavin.

Bone Spavin is a disease of the hock or tarsus of the horse, in cases of which there is a deposition of new bone around the small bones of the joint. Such a deposition interferes with freedom of movement and may cause actual lameness. An important contributing factor in the occurrence of this disease is the transmission of an undue amount of concussion to the hock joint. Such concussion does not appear to be wholly dependent upon the conformation of the joint but is influenced by a number of other factors amongst which may be mentioned bad shoeing, working young horses severely, or working horses of any age upon hard surfaces before they have become properly accustomed to them. Rotation of the limb in walking is regarded by some as being conducive to the condition, due to the straining of the ligaments of the small bones which results. Inflammation in some of the neighbouring soft structures may also lead to deposition of calcareous salts and fibrous matter in the membrane/

membrane covering the bone.

Miller (1928) states that by transmitting from parents to offspring, either some inherent tendency to the condition, or by influencing conformation so that concussion is transmitted up to the hock more than in the normal, heredity is generally held to be a potent causal factor. Koch (1926) as a result of personal observation in Germany is of the opinion that the defect is not hereditary in nature, but is rather due to unfavourable environmental conditions.

Only ten cases of stallions rejected as suffering from Bone Spavin have been considered, in the present investigation. The mean coefficient of inbreeding of these is greater than that in the breed during the same time, the difference being 1.30 $\pm$ .72.

Although not significant the difference is suggestive. Pedigrees were examined and, compared with those of the breed, showed a wider degree of inbreeding to Baron's Pride. In the breed, about 50% of stallions were inbred to Baron's Pride for period 1910-1919 whilst 80% of those stallions suffering from Bone Spavin were inbred to this sire. When compared with each other the pedigrees of these defective stallions were found to be very largely of one line of breeding on the paternal side, Baron of Buchlyvie being the sire of three, and the paternal grandsire/

TABLE XIII.

Analysis of Inbreeding amongst Stallions suffering from

Bone Spavin

Period according to year of Birth	No. of Cases	Average Coefficient of Inbreeding amongst stallions	
		Defective	in Breed
1910-14	2	4.58	4.10
1915-19	8	5.99	4.70
1910-19	10	5.70 + .72	4.40

Difference between the average coefficient of inbreeding of stallions suffering from Bone Spavin and the average coefficient of inbreeding of stallions in the Breed during the period 1910-19;

$1.3 \pm .72$

grandsire of five defective stallions. In seven of these pedigrees inbreeding to Baron's Pride took place.

The abnormal amount of inbreeding to Baron's Pride and the somewhat abnormal mean coefficient of inbreeding of the stallions suffering from Bone Spavin is strongly suggestive of the defect being hereditary in nature and connected in some way with the Baron's Pride line.

Shivering.

Whilst apparently of a nervous nature shivering occurs more frequently amongst horses of the heavy draft breeds than amongst those of the lighter breeds. The presence of the disease is characterised by spasmodic contraction of certain groups of muscles, particularly those situated in the hind quarters and tail. Although horses affected by this disease may work slowly for considerable periods, the progress of the condition ultimately renders them unfit for really strenuous work.

McCall (1910) made a post-mortem examination of the brain and spinal cords of two animals suffering from Stringhalt and Shivering, but failed to find any signs of degeneration in these parts of the nervous system. Mitchell (1930) (1931) has carried out a large number of post-mortem examinations upon horses which/

which during life were known to have suffered from Stringhalt and Shivering. He has described the various lesions found in the vertebral column and is of the opinion "that Shivering and Stringhalt are merely signs of Osteo-Arthritis affecting the vertebral column and that the varying site of the muscular spasm depends upon the nerve roots implicated".

In the present study there were available seventeen cases of stallions rejected as suffering from Shivering. The mean coefficient of inbreeding of these stallions was less than the corresponding figure for stallions in the Breed, the difference being .45 $\pm$ .56. Pedigrees of stallions suffering from the defect were examined and compared with those in the breed. They were found to differ in two respects. The percentage numbers inbred to Topgallant and Sir Everard were slightly greater than in the breed. Of defective stallions about 40% were inbred to Lord Lyon 489 to which stallion there was little inbreeding in the breed. Such inbreeding to Lord Lyon took place through mares and consequently was not indicative of any one line of breeding. In addition the coefficients of inbreeding due to this stallion were comparatively small owing to his appearing some five or six generations remote from the defective individuals whose/

TABLE XIV.

Analysis of Inbreeding amongst stallions suffering from

Shivering.

Period according to year of Birth	No. of Cases	Average Coefficient of Inbreeding amongst stallions	
		Defective	in Breed
1910-14	2	8.33	4.10
1915-19	8	4.04	4.70
1920-24	6	5.21	7.00
1925-29	1	6.86	6.46
1910-29	17	5.12 + .56	5.57

Difference between the average coefficient of inbreeding of stallions suffering from Shivering and the average coefficient of inbreeding of Stallions in the Breed during the period 1910-29;

$.45 \pm .56$

whose pedigrees were being considered. It is very remotely possible that this stallion was in some measure responsible for the propagation of the defect, which, by reason of the differences in inbreeding to Topgallant and Sir Everard, appears as if it may be hereditary.

TABLE XV.

Analysis of Inbreeding amongst stallions suffering from Stringhalt.

Period according to year of Birth	No. of Cases	Average Coefficient of Inbreeding amongst stallions	
		Defective	in Breed
1910-14	5	5.08	4.10
1915-19	28	5.56	4.70
1920-24	12	7.15	7.00
1925-29	5	7.28	6.46
1910-29	50	6.68 + .41	5.57

Difference between the average coefficient of inbreeding of Stallions suffering from Stringhalt and the mean coefficient of inbreeding of $S_t$allions in the Breed during the Period 1910-29;

$$1.11 \pm .41$$

Stringhalt.

This term is applied to a sudden snatching up of one or both of the hind legs of a horse when walking, due to an excessive contraction of the flexor muscles of the hock. The defect may be divided into two types

(1) Those due to pathological lesions of the limbs.

(2) Those caused by some form of nervous disorder, either in the brain or spinal column.

Of these, the firstnamed variety may be caused by injury to a nerve ending, such as is caused by bad shoeing. True Stringhalt apparently depends upon some change in the spinal cord whereby normal co-ordination between muscles of the limbs is disturbed. It seems very probable that the number of cases suffering from the first type of Stringhalt would definitely comprise a minority of the total number of animals rejected on account of this defect, owing to the greater ease of recognition and the possibility of the application of remedial measures prior to examination for the purpose of licensing under the Horse Breeding Act. For this reason the material may be assumed to be relatively free from "false" forms of the defect.

Fifty cases of Stringhalt have been considered. Compared with that of stallions in the breed their mean coefficient of inbreeding is greater, the difference being 1.11 $\pm$ .41. Such a difference is greater/

greater than that shown in the case of any of the other defects treated. Pedigrees were examined and compared with breed stallions. It was noted that there was a distinct difference in inbreeding to Macgregor. The percentage of animals inbred to this stallion amongst defectives was 43 while that in the breed was ten. Certain differences from the normal breeding practice which exist in the pedigrees of defectives were most strongly pronounced in those occurring in the class 1915-1919 which contains the largest number of cases, amounting to 28. In this group the stallions Royal Favourite, Sir Everard, Revelanta and Everlasting appear in the pedigrees with abnormal frequency. Nineteen cases of inbreeding to Baron's Pride occurred in this group, such being similar to the frequency in the breed. In the remaining nine cases Baron's Pride appeared on one side of the pedigree and on the other side in order of frequency were found Macgregor (1487), Hiawatha, (10,062) and Sir Everard.

The data would therefore seem to indicate that the defect of Stringhalt is hereditary in nature. The factors involved in its transmission appear to be found very largely in the Darnley and to a much lesser extent in the Prince of Wales line.

To postulate that the Darnley and Prince of Wales/

Wales lines are implicated practically amounts to condemning the entire Clydesdale breed. Such a hypothesis must be more limited in application and, keeping in view the above findings, one is inclined to conclude that the factors involved in the propagation of the defect, though largely, are not solely confined to one line.

The wider incidence of inbreeding to Macgregor amongst stallions suffering from this defect is rather significant despite the sound reputation which this stallion bears. It appears that the condition has a greater chance of arising when certain factors from Macgregor combine with either (a) factors from Baron's Pride or (b) other factors from Macgregor. That the factors are also apparently to be found in the Prince of Wales line is suggested by the appearance of Hiawatha next in order of frequency to Macgregor in conjunction with Baron's Pride in pedigrees of stallions suffering from Stringhalt.

Roaring and Whistling.

These terms are applied to an abnormality in breathing caused by a weakness in the larynx and are descriptive of the sounds produced when the horse's respiration is laboured. The sounds arise from interference with the stream of inspired air such interference being due to the paralysis of nerves supplying/

supplying muscles which normally move the arytenoid cartileges outwards. Various respiratory diseases such as colds, influenza, and pneumonia may give rise to the condition but it may also arise spontaneously from unknown causes. A horse which whistles may become a "roarer" but a change in the opposite direction is extremely uncommon, roaring is the more serious defect in that it usually causes loss of condition due to improper oxygenation of blood in the lungs.

Koch (1926) has indicated the necessity of distinguishing between cases caused by respiratory diseases and those due to paralysis of the primary recurrens. He agrees with the general opinion that the latter form is hereditary in nature but believes that it is wrong to seek the cause in the peculiar anatomical relations of the lung recurrens since, despite the fact that these are the same in all animals, the defect is exhibited by comparatively few.

Schmidt (1913) made an analysis of pedigrees of defective horses found in the Trakehnen Stud and demonstrated the existence of four female lines in which the incidence of whistling was abnormally great. A certain sound and much used stallion "Odoardo" was shown by him to have transmitted whistling to certain of his sons. One mare which had produced roarers when/

when mated with three different stallions was discovered. Daughters of this mare which themselves were sound, produced roarers when mated to certain stallions.

Schutt (1927) has given several examples of matings of roaring stallions and sound mares, which produced "roaring" offspring. Saks (1927) has made a very complete study of roaring in thoroughbred horses and estimates that about 2% are affected by various hereditary forms of this defect. He has observed that roaring first becomes manifest when the animal is fully grown, developed and sexually mature and is in no way connected with faulty training or over-work. The opinion that there exists a "predisposition" which requires only certain conditions for its expression has, in his opinion, to be refuted as being incorrect and not based on fact. Furthermore, a hereditary factor for the defect is either present, in which case roaring will be exhibited at sexual maturity, or such a factor is absent and the most strenuous training and racing will fail to provoke the condition. He cites the case of the mare Sibryz, a roarer, who produced healthy offspring. Two of her sons were used for breeding purposes and roarers appeared among the offspring of one of them. The defect, he maintains, is transmitted to only a few of the immediate offspring but occurs more frequently in/

in the second and third generations.

When the pedigree of the race horse Ajax, whose sire Flying Fox was in Saks' opinion one of the best horses in France, was extended to five generations it was found that seven roarers appeared amongst his progenitors. Ajax himself was exceptionally sound as were also his offspring. Examination of pedigrees would seem to suggest that roaring appears only in these cases where the hereditary tendency is introduced by both parents, but that the offspring are unaffected when it is introduced by one parent only.

The existence of families in which whistling is abnormally frequent, as was demonstrated by Schmidt for the Trakehnen Stud, would seem to suggest that the defect is hereditary in nature. Matings, of which examples have been given by Schmidt, Schutt and Saks apparently show that roaring and whistling are hereditary and behave as simple Mendelian recessives. Saks is in disagreement with the theory of the existence of a hereditary predisposition to the condition.

In the present investigation 64 cases of roaring were considered. Compared with figures for stallions in the breed the mean coefficient of inbreeding of these defective stallions was greater, the difference being .40 $\pm$ .36. The results are in Table XVI on page

The pedigrees of these stallions were examined and/

TABLE XVI.

Analysis of Inbreeding amongst stallions suffering from

Roaring.

Period according to year of Birth	No. of Cases	Average Coefficient of Inbreeding amongst stallions	
		Defective	in Breed
1905-10	10	6.24	3.70
1910-14	14	4.46	4.10
1915-19	23	5.39	4.70
1920-24	14	6.34	7.00
1925-29	3	6.66	6.46
1905-29	64	5.59 + .36	5.19

Difference between the average coefficient of inbreeding of stallions suffering from roaring and the average coefficient of inbreeding of stallions in the Breed during period 1905-29;

$.40 \pm .36$

and two peculiarities were noted. Compared with stallions in the breed, the number of matings between the Prince of Wales and Darnley lines is abnormally great such being due to matings of Baron's Pride stallions and Hiawatha mares.

In addition, the inbreeding to Prince of Wales amongst roaring stallions was greater than in the breed. In group 1905-1909 100% of defectives were inbred to Prince of Wales compared with 80% in the breed. The average percentage of inbreeding to Prince of Wales amongst defectives in this group was 1.28 while that in the breed was .72. The results of this analysis are given in Table XVII.

Of the defect of Whistling only twelve cases were available of which the years of birth extend over four periods from 1905-1924. The mean coefficient of inbreeding of these stallions is greater than that of stallions in the breed, the difference being 1.71 ± .89.

The largest class 1915-1919 contains eight cases all of which were inbred to Baron's Pride. In the breed at this time the percentage of animals inbred to this stallion was 67. With regard to the types of breeding practice there is much less crossing of the two main lines than was noted amongst the class of stallions suffering from roaring. Such crossings as did take place also produced inbreeding to Baron's Pride/

TABLE XVII.

Analysis of Inbreeding amongst Stallions suffering from Roaring, 1905-1909.

	Class	Baron's Pride	Sir Everard	Top-gallant	Prince of Wales	Darnley
Percentage No. of animals inbred to stallion	Roarers	20	10	20	100	90
	Breed	8	11	11-50	89	86
Percentage amount of inbreeding to stallion amongst animals inbred to him	Roarers	9.38	3.91	.59	1.28	1.05
	Breed	7.64	3.56	.67	.81	1.39
Percentage amount of inbreeding to stallion in the same of population considered	Roarers	1.88	.39	.12	1.28	.943
	Breed	.59	.31	.03-.34	.72	1.18

Pride. The inbreeding to Sir Everard and Macgregor is somewhat greater amongst Whistling stallions than amongst animals in the breed during the same period of time.

A consideration of the data upon roaring and whistling would seem to suggest generally that the first defect is transmitted through two lines while the latter is transmitted through one. The factors for roaring seem to be present in both the Baron's Pride and Prince of Wales lines whilst those connected with whistling are apparently to be found mainly in the Baron's Pride line of descent. Association of factors due to crossing between the Hiawatha and Baron's Pride line or matings in which there is an abnormal amount of inbreeding to Prince of Wales, apparently tends to give rise to stallions suffering from roaring whilst a sub-normal amount of crossing between the two lines with a large amount of inbreeding to Baron's Pride apparently tends to give rise to whistling stallions. In view of the fact that Sir Everard, sire of Baron's Pride also figures abnormally in the pedigrees of stallions in the whistling class it is possible that this stallion may be partially responsible for the propagation of both defects.

TABLE XVIII.

Analysis of Inbreeding amongst stallions suffering from

Whistling.

Period according to year of Birth	No. of Cases	Average Coefficient of Inbreeding amongst stallions	
		Defective	in Breed
1905-09	1	1.42	3.70
1910-14	2	6.56	4.10
1915-19	8	7.61	4.70
1920-24	1	3.72	7.00
1905-24	12	6.59 + .87	4.88

Difference between the average coefficient of inbreeding of Stallions suffering from Whistling and the average coefficient of inbreeding of Stallions in the Breed during the period 1905-24;

$1.71 \pm .87$

Discussion of Results.

In the previous section, for each defect, reference has been made to the environmental influences which play an important part in its incidence. There are many and diverse opinions of the rôle which environment plays, but very little classified knowledge exists. Nevertheless it is recognised that it is impossible accurately to assess the total effect of environment. This is especially true of the bone diseases, Ringbone and Sidebone where the age and treatment to which the animal has been subjected exert a profound influence upon the occurrence of the defects. In the opinion of Miller, the occurrence of Bone Spavin is to a much lesser extent affected by external conditions. Various affections which may give rise to Roaring and Whistling have already been indicated.

In addition to being influenced by environmental effects, the pursuit of an investigation such as the present one is further complicated by reason of the peculiar structure of the Clydesdale breed. Such complication is introduced by reason of the fact that the breed is entirely composed of two main lines of descent viz., Prince of Wales and Darnley, of which the latter is strongly predominant. Indeed, Calder (1927) and the present writer have shown that practically all animals in the Breed, foaled in recent years, are inbred to Baron's Pride. Thus, the fact that many are inbred/

inbred to Baron's Pride is insignificant, unless the proportion is greater than that in the Breed during the same period of time. Hadley and Cole (1928), in the Holstein Friesian breed of cattle, have shown that 55 calves suffering from Epithelial defects belonged to 18 herds, each of which could be traced to matings of Sarcastic Lad and cows of the Johanna family. Owing to the non-existence of several distinct foundation families in the Clydesdale Breed it has been impossible to trace, in this manner, defects of the breed to their source.

Reference has already been made to studies of the inheritance of human defects, in which it has been shown that a hereditary defect which is expressed but rarely in a population is characterised by an abnormally high degree of consanguinity amongst parents of persons in whom the defect is apparent. The defects for which the greatest numbers were available in this study were Roaring and Stringhalt. Over a period of twenty years the number of stallions rejected for Stringhalt was fifty, while during a period of only fifteen years the number rejected for Roaring was sixty-four. Of stallions suffering from these two defects it is also possible that a larger number of Roaring than of Stringhalt stallions would be withheld from examination, due, in many cases, to the/

the greater ease of detecting the former condition in young animals. There is thus some reason to believe that Roaring occurs more frequently than Stringhalt. The average degree of inbreeding of Stringhalt Stallions is abnormal to that in the breed, the difference being 1.11 ± .42. Such a difference in the case of Roaring Stallions is only .40 ± .36. These differences in frequency of occurrence and of abnormality of inbreeding in the case of the two defects are such as to slightly suggest that heredity plays some part in the transmission of one or both.

Roberts (1926) in a paper on "A Lethal Deformity in New-Born Lambs" has observed that the result of inbreeding is to produce strains that are relatively pure as regards their hereditary constitution. Defects where hereditary and inherited in a dominant manner would be relatively simple to eradicate. That the problem is of a more difficult nature is evident by reason of the persistence of defects in the Clydesdale Breed, despite the efforts of horse breeders; and indeed it may be said that it was very largely in recognition of the complexity of the problem that a measure such as the Horse Breeding Act 1918 was passed. One may assume then with reason that most defects in the Clydesdale Breed where hereditary are inherited in a recessive or partially recessive manner. If this is so, abnormal inbreeding will tend to unmask them/

them and if animals suffering from such a defect are grouped together it is very probable that their average degree of inbreeding will be greater than that in the breed during the same period of time.

In this study stallions in the Clydesdale breed have been grouped according to the defect from which they were found to suffer. Under such methods of grouping there is a significantly abnormal degree of inbreeding in the case of one defect - Stringhalt. Compared with the inbreeding in the breed there is in this case a positive difference of 1.11 $\pm$ .41. For two other defects, Whistling (1.71 $\pm$ .87) and Bone Spavin (1.3 $\pm$ .72), there are exhibited differences which though barely significant statistically are nevertheless suggestive, especially when considered in relation to individual pedigrees. The number of cases of these defects which were available for purposes of the present study was unfortunately rather small, being respectively twelve and ten.

Cases of three defects, Sidebone, Bone Spavin and Whistling show an abnormal degree of inbreeding to animals of the Baron's Pride line of descent. Stallions suffering from Stringhalt and Roaring are characterised by crossing between animals of the two main lines of descent in the breed. It is interesting to note that Roaring and Whistling apparently arise as the/

the result of two different types of breeding practice, cases of Whistling being largely of one line of descent. Thus the average coefficient of inbreeding amongst stallions suffering from Whistling is greater than that of stallions suffering from Roaring when both are compared with contemporary figures for the breed. Only one defect, Shivering, shows a degree of inbreeding which is less than that in the breed during the same period of time.

Summary.

1. An examination of the pedigrees has been made and the coefficients have been calculated for stallions for whom licences had been refused under the Horse Breeding Act 1918 in respect of the following defects Ringbone, Sidebone, Bone Spavin, Shivering, Stringhalt, Roaring and Whistling.

2. Both from a comparison of the average coefficient of inbreeding and from an exact examination of pedigrees with relation to those in the Breed the evidence is such as strongly to suggest thst Stringhalt is a hereditary defect.

3. When compared with animals in the breed an examination of the pedigrees of stallions possessed of Whistling and Bone Spavin would seem to suggest, though less strongly, that the defects are also hereditary. It was unfortunate that the number of cases available for purposes of this study were not greater.

4. Owing to the predominance of the Baron's Pride line of descent in the breed there is a uniformity in the pedigrees of animals in the breed. In this study animals possessed of one of three defects, Sidebone, Bone Spavin and Whistling, show abnormal degrees of inbreeding to animals of this line of descent.

5/

5. From an exact examination of pedigrees of animals possessed of Sidebone and Roaring the evidence is such as not to preclude the possibility of their being genetic in origin.

6. With regard to Ringbone there was insufficient evidence upon which to base any conclusions as to whether or not it was of genetic origin.

7. The evidence upon Shivering is also neither positive nor negative and the point must remain open. The numbers on which this study was based are very small.

8. A study of pedigrees would seem to show that defective stallions cannot be treated as a group. While there may be some common physiological basis for these defects, their expression, where hereditary, would appear to be due to different factors.

Part IV.

The Montrave Stud.

Moss Rose (6203)

Photograph of Statuette in Bronze in the possession of Sir John Gilmour

Introduction.

The advantages of possessing results of an investigation into the inbreeding in a breed have already been enumerated. Such variations in inbreeding as have been noted indirectly express the degree of selection practised in the breed at different stages of its existence. It is fairly obvious though that these variations in inbreeding in the breed are the result of variations in inbreeding which have taken place in its units - the studs. An analysis of inbreeding in a breed is therefore rendered more complete by the addition of the knowledge arising out of similar analyses of inbreeding in the principal studs of which it is composed. A supplementary analysis of this type has been carried out for the Montrave Stud.

This stud had its foundation in purchases made by the late Sir John Gilmour Bart., from Mr. John W. Martin of Auchendennan in 1879. These were augmented in 1884 by the acquisition of the stallion Garnet Cross (1662) which had formerly belonged to Mr. A. Brackenridge of Stevenston Mains, for the sum of £700. Probably the most famous addition to the stud was made in 1885 when Moss Rose (6203) was bought from Messrs. A. and W. Montgomery of Netherhall Kirkcudbright at a price of £800.

This/

This mare had already embarked upon what later proved to be one of the most wonderful showyard careers known in the breed. Before entering the Montrave Stud she had already been first as a two-year-old at the Royal Show in 1883 and Champion at the Highland Show in the following year. In the Montrave Stud her successes continued, and culminated in winning the Cawdor Cup at two consecutive Highlands in 1894 and 1895, when she was 13 and 14 years old. With ten other Championships to her credit, she died in 1908 at the age of 27 years.

Her merit was by no means confined to the Showyard. Of her nine foals, one, Montrave Rosea (12,302) by Prince of Albion (6178) was sold in 1892 as a two-year-old for 1,000 guineas, which was the highest price at the Montrave Draft Sale held in that year. In the following year this mare won the Cawdor Cup under the name of "Queen of the Roses". Another daughter, Montrave Maud (11,786) by Prince of Wales (673) was twice winner of the Cawdor Cup - in 1896 and 1898. Moss Rose was also the dam of Montrave Mac (9958). This stallion, by Macgregor (1487), was sold to W. Dunlop, Dunure Mains at a price of £1,000 when rising two-years-old and proved himself to be a successful sire.

Another distinguished mare, Lady Victoria (14582)/

(14582), by Baron's Pride 9122, was purchased by Sir John Gilmour in 1889 for 400 guineas, having already won the Cawdor Cup. In addition to her individual merit she proved to possess distinct ability as a breeder of high class stock. One of her sons, by Hiawatha (10,067), Montrave Viceroy(14278) stood reserve to Dunure Footprint for the Cawdor Cup in 1910 and to Marathon for the same honour in the following year. A full sister to Montrave Viceroy, Montrave Vanda (32752) made the top price of 625 guineas at the Dispersion Sale in 1914.

The average age of Brood Mares at Montrave was 12 years and the average number of progeny was four. These figures were taken from records of Brood Mares which had not been sold out of the stud.

The early stallions used at Montrave were Garnet Cross (1662), Prince of Albion (6178) and Brooklyn (6547), and were all the property of Sir John Gilmour.

Of these, the most famous was Prince of Albion who, as a two-year-old came, in 1888, from Craigie Mains to Montrave at a price of £3,000. His showyard career is probably one of the most remarkable in the breed. Prior to his entry into the Montrave Stud he had already been first in his class in two consecutive "Highlands" as a yearling in 1887 and as a two-year-old. Whilst in the Montrave Stud he was first in the same/

same show as a three-year-old and four-year-old. His total number of "firsts" was sixteen and in 1889 he was also winner of the Queen Victoria Gold Medal as a three year old at the Royal Show at Windsor.

At the draft sale in 1892 all the yearling and two-year-old colts and fillies on offer were sired by Prince of Albion. Reference has already been made to the price of 1,000 guineas obtained for his daughter Montrave Rosea as a two-year-old. The average prices realised for them at the 1892 Sale were as under -

Class	No.	Average Price
One year old Colts	7	£ 60:18: 0
Two " " "	2	141:15: 0
One year old Fillies	4	106: 6: 3
Two " " "	3	481: 5: 0
Total	16	161: 3: 6

Figures such as these show the high esteem with which Prince of Albion was regarded as a sire. Standing at Montrave during the season 1890 his terms were 15 guineas, foal or no foal.

Brooklyn (6567) was bought from the Heir Trustees at the Sale in 1891 at a price of £700 and remained in Sir John's possession until 1905 when he was sold to Mr. W. Henderson, Woodside, Doune. During this time he was used successfully with several of the Montrave mares. Outside the Stud he also proved himself to be a getter of good quality selling stock. Unlike Prince of Albion or Garnet Cross, who were both bays, he/

he was dark brown in colour and showed very little white markings, having only a small spot on the face and white hind pasterns. A note on season 1896 shows that he served 81 mares and got 48 foals.

During the seasons 1898 and 1899 Macgregor (1487) the property of Messrs. Montgomery of Netherhall was stud horse at Montrave. His terms were 10 guineas for service. During 1898 he served 20 Montrave mares and 25 outside mares. Himself of vigorous constitution, his stock were greatly valued on account of their robustness.

Later such outstanding sires of the breed as Baron's Pride (9,122) Royal Gartly (1804), twice Cawdor Cup winner, and Hiawatha (10,067) were used at Montrave, a daughter of the last mentioned stallion, Montrave Vanda (32,752) making the highest price of the 1914 Dispersion Sale. Hiawatha was also mated successfully with several Montrave mares by Baron's Pride, the four mares which averaged £349: 2: 6 at the sale in 1914 having been bred in this way.

Such notable sires as Montrave Ronald (11121), Baron Gibson (12,452) Baron of Buchlyvie (11,263) and Dunure Footprint (15,203) were also used during the final year of the existence of the stud which was finally dispersed in 1914 at Lanark when for 14 head an/

an average of nearly £160 was obtained.

The above historical account may serve to show the important part which the Montrave Stud played in the Clydesdale Breed, during its thirty five years of existence.

Material.

The data for this study has been based upon information contained in records of the Montrave Stud of Clydesdale horses, the property of the late Sir John Gilmour, Bart., of Lundin and Montrave which through the courtesy of the present Minister of Agriculture have been placed at the disposal of the Institute of Animal Genetics.

These records are in three volumes, and the method of recording adopted is worthy of special mention. Each page is designed to accommodate particulars of four horses. A well-finished full plate print of each animal is followed by its name, stud book number, and date of foaling. In the case of horses which have not been bred at Montrave, the name or names of previous owners and purchase price precede the pedigree. The manner of disposal or date of death of each animal is also given. In addition, a complete account of showyard career and honours won accompanies each pedigree. The produce of mares is also recorded, together with sires and dates of birth.

Method.

The pedigrees of all the stallions and mares were extended and tabulated to the seventh generation. The degree of inbreeding in each animal was calculated, using Sewall Wright's Coefficient. The total number of animals thus treated amounted to 258.

Results.

In order to demonstrate the variation in inbreeding in the Stud, the period during which the latter had been in existence was divided up into five-year classes corresponding to those employed by Calder. The first of these began in 1875 and the last ended in 1915. In these classes, the coefficients of inbreeding of animals in the Stud were arranged according to the animal's year of birth. The mean coefficient of inbreeding of mares, stallions and of the Stud is shown for each five-year period in Table

Variation in Inbreeding in the Stud.

Examination of TableXIX which is illustrated graphically on page87 reveals the following facts regarding the course of inbreeding in the Stud.

Inbreeding did not appear in the Stud till the period 1880-85. There was an almost uniform increase in average coefficient of inbreeding from that time till the period 1900-1905, when the value reached was 5.8./

T A B L E XIX .

INBREEDING in the MONTRAVE STUD.

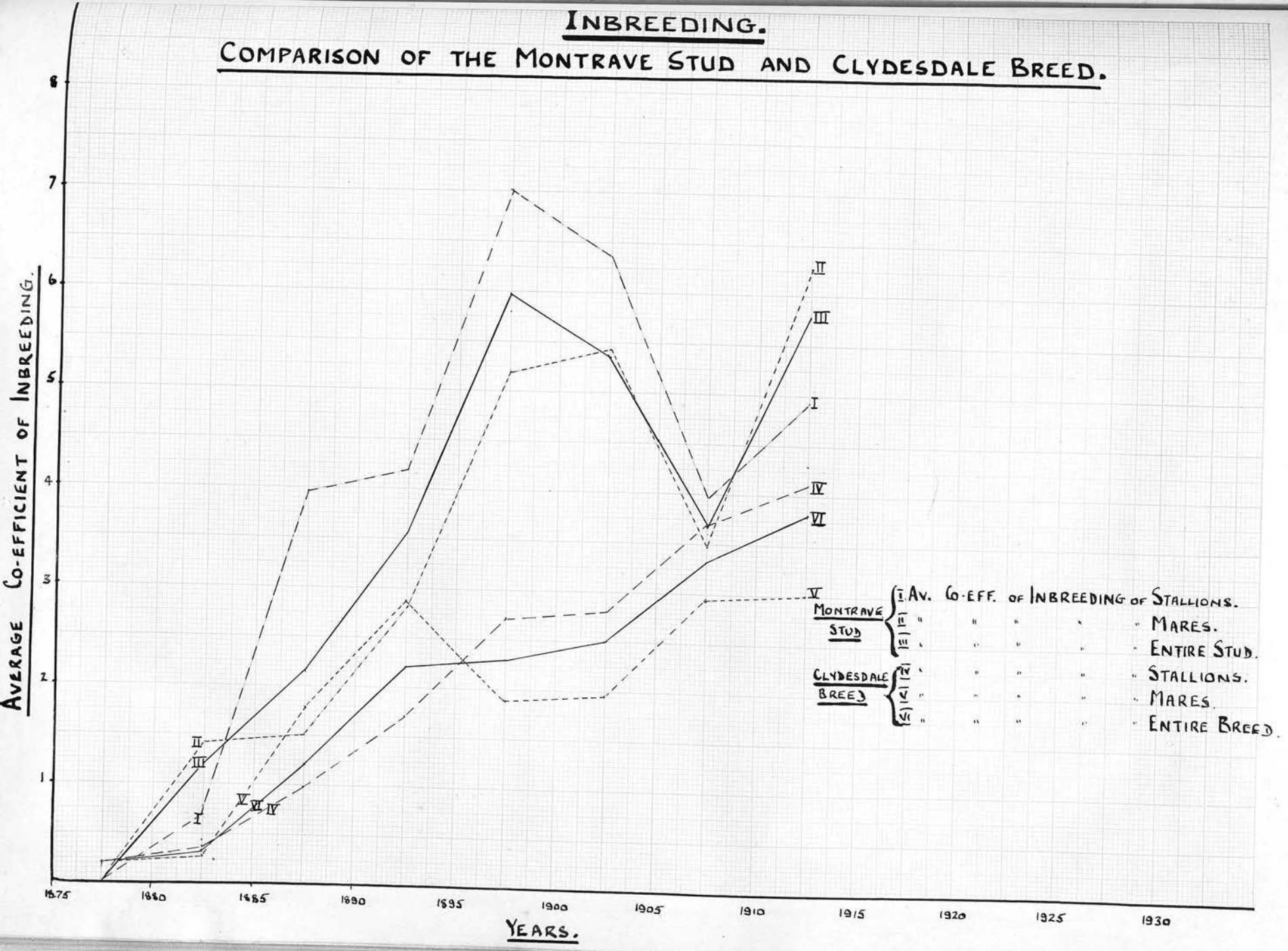
SUMMARY of RESULTS.

PERIOD.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	
DATE.	1875-80	1880-85	1885-90	1890-95	1895-00	1900-05	1905-10	1910-15	CLASS.
S.	0	3.541	35.687	154.970	126.595	108.390	51.916	24.629	
N.	2	5	9	37	18	17	13	5	Stallions.
A.	0	.708	3.965	4.188	7.033	6.376	3.993	4.926	
S.	0	17.042	37.558	92.471	124.745	119.625	66.022	33.136	
N.	5	12	25	33	24	22	19	5	Mares.
A.	0	1.420	1.502	2.802	5.198	5.438	3.475	6.626	
S.	0	20.583	73.245	247.441	251.340	228.015	117.938	57.792	
N.	7	17	34	70	42	39	32	10	All.
A.	0	1.211	2.154	3.535	5.984	5.846	3.683	5.779	
SUMMARY									
A.	0	.71	3.97	4.19	7.03	6.38	3.99	4.93	Stallions.
A.	0	1.42	1.50	2.80	5.20	5.44	3.48	3.63	Mares.
A.	0	1.21±.28	2.15±.36	3.54±.24	5.98±.40	5.85±.40	3.68±.35	5.78±.66	All.

Where S. Sums of Coefficients of Inbreeding.
" N. Number of Cases.
" A. Average Coefficient of Inbreeding.

INBREEDING.

COMPARISON OF THE MONTRAVE STUD AND CLYDESDALE BREED.



GRAPH 6

5.8. There was a depression of inbreeding in the following period to 3.7 followed by an increase to 5.8 in 1910-1915.

When compared with results for the Stud, the figures for the stallions and for mares show a difference in their mode of variation. The number of stallions considered in the period 1880-1885 is too small to be significant. After this period, the level of inbreeding among stallions tends to be higher than the level of inbreeding in the Stud as a whole. Throughout the whole of the time considered after period 1880-1885, the mares show a lower level of inbreeding than that of the Stud.

Comparison with Breed.

The analysis of the Montrave Stud extends from 1875 to 1915. A comparison of the breeding practised in the Clydesdale breed during the corresponding period reveals the fact that there is a greater intensity of inbreeding in the former than in the latter. Between 1875 and 1880, this condition is reversed, but the number of animals considered in the Stud during this period is small amounting to 7 in all. The time during which the greatest difference in intensity of inbreeding occurs is from 1895 to 1905.

With a view to examining the factors concerned in these changing relationships between the amount of inbreeding in the Montrave Stud and in the Clydesdale Breed/

TABLE XX

Inbreeding to Prominent Sires in the Montrave Stud and in the Clydesdale Breed.

No. of Five Year Period	"SAMSON" (1855)			"LOCHFERGUS CHAMP" (1861)			"PRINCE OF WALES" (1866)			"PRINCE OF WALES" (1866)			"DARNLEY" (1872)			"DARNLEY" (1872)		
	MONTRAVE			MONTRAVE			MONTRAVE			BREED ✠			MONTRAVE			BREED ✠		
	(a)	(b)	(d)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
3													4	6.25	.27			
4							6	4.69	.27	4	1.72	.07	30	4.93	1.46	10	4.37	.43
5				28	3.20	.89	35	3.55	1.24	23	2.79	.63	50	3.97	1.99	27	3.67	.99
6	6.6	1.17	.08	44	1.27	.56	18	3.33	.70	43	1.61	.69	74	3.65	2.71	44	1.95	.87
7	14.3	.61	.09	55	.42	.25	71	2.53	1.85	48	1.64	.78	68	1.85	1.25	78	1.38	1.07
8	33.4	.49	.17	64	.93	.60	76	1.46	1.11	89	.80	.72	60	1.20	.72	86	1.39	1.18
9	56.9	.39	.22	40	.26	.11	64	.74	.47	92	.78	.72	100	.87	.87	92	1.08	.98
10	81.4	.41	.33	27	.14	.04				100	.62	.62				100	1.03	1.03
11	94.4	.29	.27	45	.09	.04				100	.56	.56				100	.98	.98
12	87.5	.23	.20															

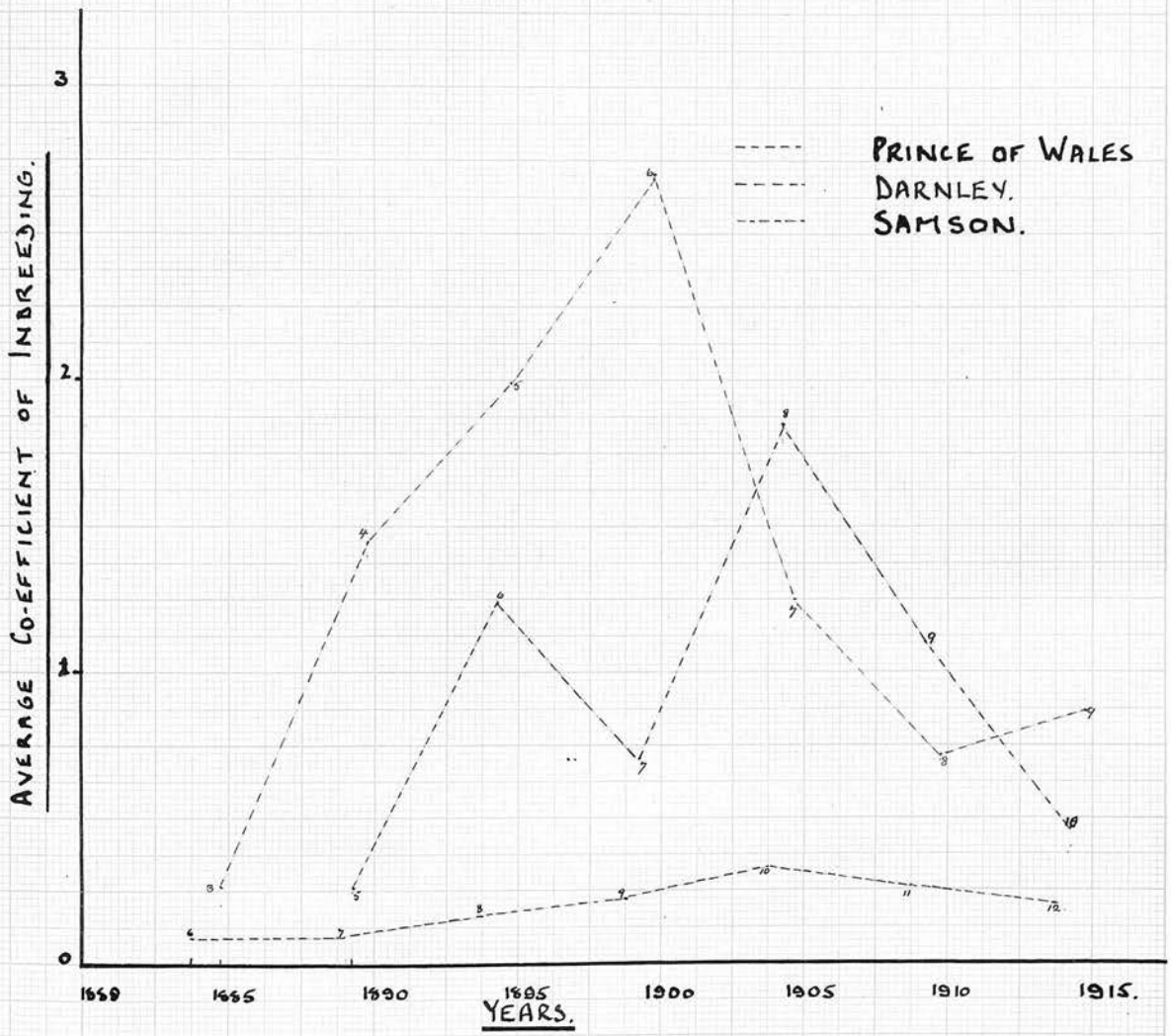
Where (a) .. Percentage of Animals inbred to Stallion during each five-year period.
" (b) .. Average percentage of inbreeding for Animals inbred to Stallion.
" (c) .. Average percentage of inbreeding to him in each sample of population considered.

✠ Figures taken from paper by Calder (1927)

GRAPH 7

DEGREE OF INBREEDING ATTRIBUTABLE TO PROMINENT SIRES.

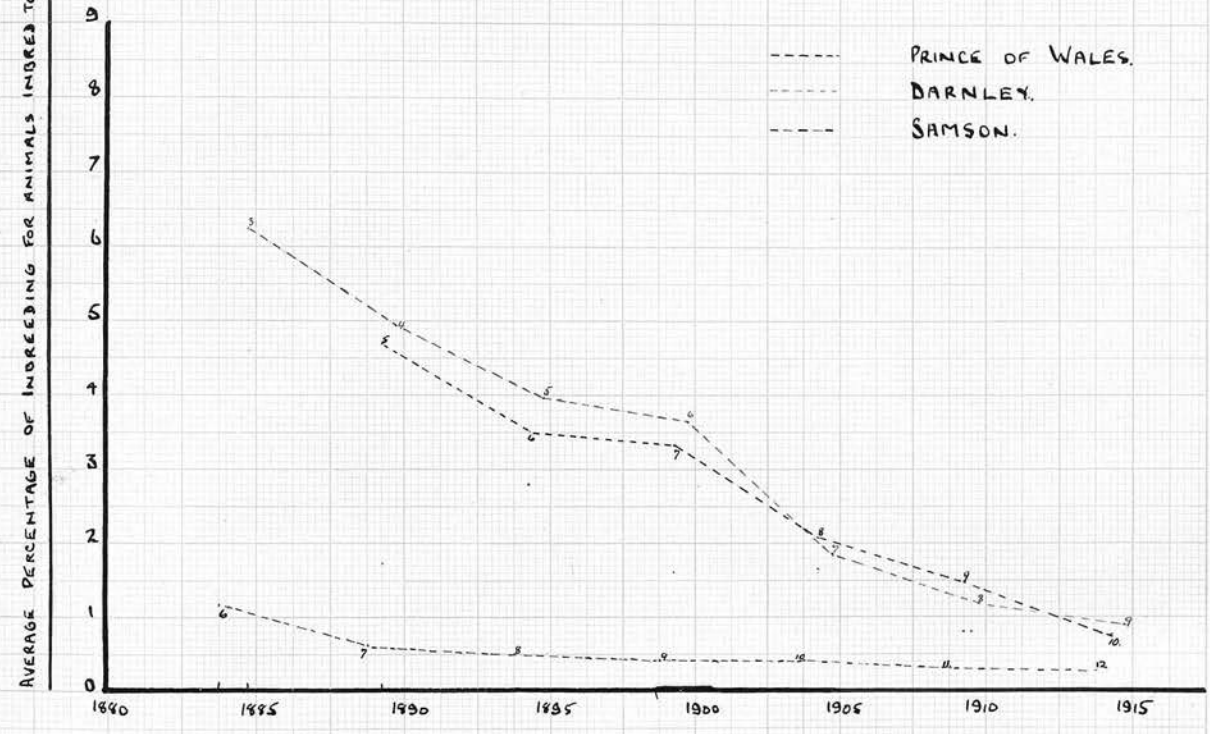
(SEE TABLE XX COLUMN C)



GRAPHS 8 AND 9

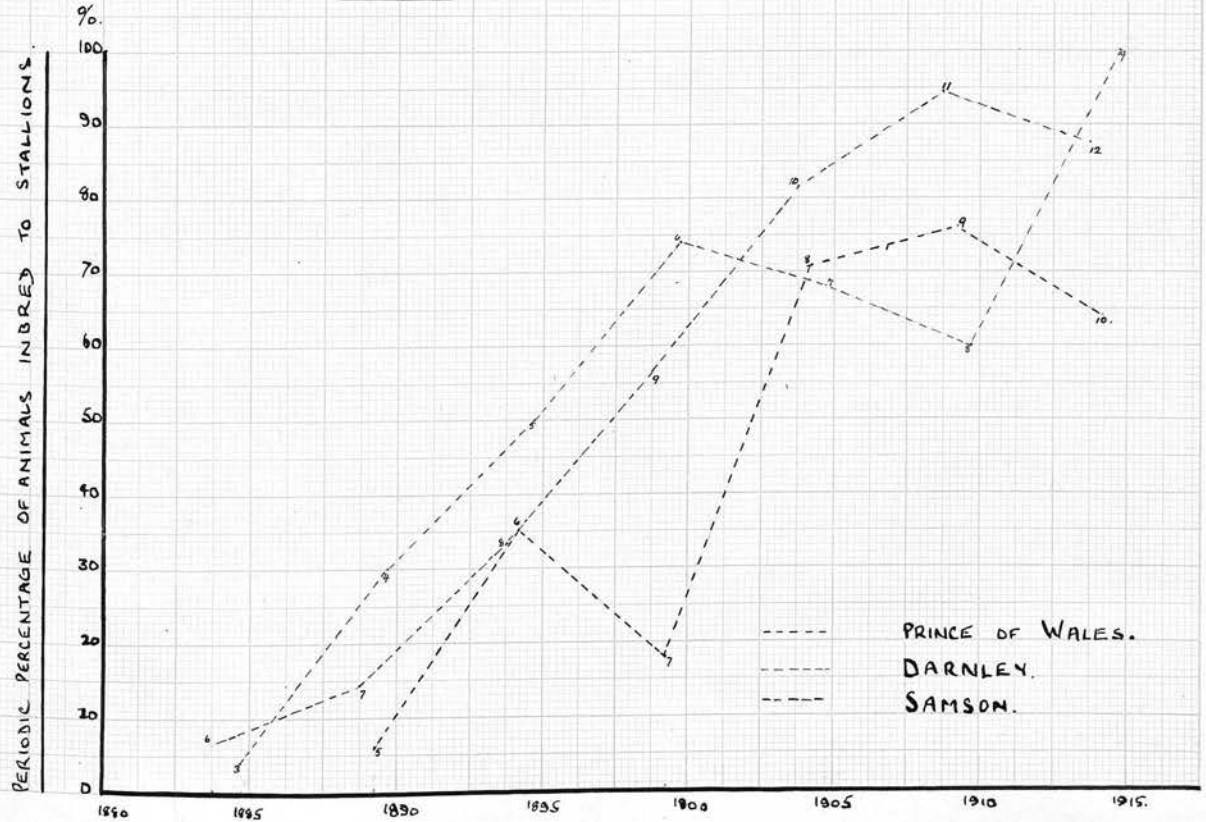
INTENSITY OF CONCENTRATION OF "BLOOD" OF PROMINENT SIRES.

(SEE TABLE XX COLUMN b)



RATE OF CONCENTRATION OF "BLOOD" OF PROMINENT SIRES.

(SEE TABLE XX COLUMN a.)



Breed, an analysis of the inbreeding to prominent sires was made. This is incorporated in Table XX In order that the variations of inbreeding to different stallions may be readily compared, time is denoted by periods, each of five years' duration, subsequent to the birth of each stallion. Thus period seven for Darnley foaled in 1872 extends from 1902 to 1906. Period seven for Prince of Wales foaled in 1866 extends from 1896 to 1900. An examination of these figures shows this change to be due to a change in breeding practice taking place at this time, in the Stud.

In the Montrave Stud between 1895 and 1905 there was a large increase in the average percentage of inbreeding to Darnley, and at the same time, there was a decrease in the corresponding figure for Darnley in the breed. This decrease appears to be due to the mating of stallions of the Darnley line of descent with Prince of Wales mares. That this type of mating was also practised in the Montrave Stud is seen by the temporary increase in the average percentage of inbreeding to Samson (741), the maternal grandsire of both Prince of Wales and Darnley.

Incidentally, this relationship of Samson to both Darnley and Prince of Wales may account for some of the successes associated with a combination of/

of the two lines of descent. It is remotely possible that some sex-linked characters may be brought together in this way.

Between 1905 and 1910, however, there is a rapid decrease in the amount of inbreeding in the Montrave Stud. During this period, the amount of inbreeding in the Breed was increasing steadily. An explanation for this difference is to be found in the analysis of inbreeding. The time 1905-1910 coincides approximately with the ninth period of Prince of Wales and with the eighth period of Darnley as used in Table Examination of figures for these periods shows that at that time there was a decrease in the average percentage of inbreeding to Darnley in the Montrave Stud while in the Breed, the percentage of inbreeding to Darnley was gradually increasing. The average percentage of inbreeding to Prince of Wales in the Breed and in the Stud was fluctuating.

As was to be expected from the above observations a survey of the pedigrees in the Stud revealed the fact that the crossing between the Darnley and Prince of Wales lines, which had taken place earlier in the Breed, was now taking place in the Montrave Stud. The Clydesdale Breed between 1905 and 1910 was showing an increase in inbreeding due to breeding among the progeny of the crossing of the Darnley and Prince of Wales/

Wales lines.

This sequel to the crossing of the two lines was not experienced in the Montrave Stud until 1915.

Prizewinners.

In order to make an analysis of prizes won by animals in the Stud, an examination was made of the Stud Books. In these, a complete record of prizes won by each animal is given. It was decided to divide the shows mentioned into two classes.

(a) The Highland and Royal Shows.
(b) Other Shows.

Upon examination, it was seen that some animals had won several prizes at the Highland and Royal Shows and many prizes at other shows. In order, therefore, to avoid undue bias in the figures, it was decided that an animal could at most only count twice - once in the (a) and once in the (b) class.

The value attached to awards in the (a) class is greater than that attached to those in the (b) class.

The first six places were therefore recognised in the shows of the (a) class, while the first three only were recognised in the (b) class shows.

The horses counting in this way were grouped in five-year periods according to date of birth. These periods were the same as those employed in the analysis of inbreeding in the Breed as a whole. The average coefficient of inbreeding of horses in these groupings was/

TABLE XXI

MONTRAVE STUD.

Analysis of Prizewinners.

Period	Highland and Royal Shows		Local Shows		Average Coefficient of Inbreeding of		
	Number of Winners	Average Coefficient of Inbreeding of Winners	No. of Winners	Av. Coeff. of Inbr. of Winners	All animals Montrave Stud.	All animals Clydesdale Breed.	First Six Prizewinners Glasgow Stallion Show
I (1875-80)	0	0	1	0	0	.25	.818
II (1880-85)	7	1.417	1	3.906	1.6	.30	.470
III (1885-90)	8	2.929	8	.599	1.67	1.25	.698
IV (1890-95)	8	2.757	8	3.677	3.37	2.25	4.247
V (1895-00)	6	4.108	9	5.643	3.57	2.35	4.357
VI (1900-05)	7	3.579	10	5.57	6.3	2.6	2.885
VII (1905-10)	2	1.970	3	2.46	3.57	3.4	4.311

was calculated. The results are in Table XXI.

Examination of the results show several differences of inbreeding amongst the classes considered. Owing to the lack of uniformity of numbers from which the averages are compiled, such differences as exist can merely indicate tendencies in certain directions. The results are therefore put forward with this qualification.

The level of inbreeding among animals who figured in the Highland and Royal Shows is lower than that of the Montrave Stud. Both, however, are at a higher level than that which prevailed in the Clydesdale Breed during the same time. The level of inbreeding amongst the "First Two" Prizewinners in the Three-Year-Old Class of the Glasgow Stallion Show differs very little from that in the Montrave Stud during the period 1885-1910 when figures for the former are available.

It is rather interesting to note that the period 1895-1905, during which the inbreeding in the Montrave Stud differed most markedly from the breed is distinguished by the fact that during this time, animals in the Stud figure prominently in the Prize Lists.

Summary.

1. A survey of breeding practice in the Montrave Stud has been made in comparison with that in the breed.

2. It has been shown that outcrossing in the Prince of Wales line took place later in the Montrave Stud than in the breed.

3. During the thirty-five years of the Stud's existence the level of inbreeding was higher than that in the Clydesdale Breed.

4. A comparative examination of prizewinners was made and the existence of several differences with regard to inbreeding has been demonstrated.

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