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RELATIVE INFLUENCE OF THE SIRE AND DAM UPON THE
INHERITANCE OF SPEED IN STANDARD
TROTting HORSES

by

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I INTRODUCTION

Since the study of the transmission of character began, a diversity of opinion has existed and some data have been secured upon the relative influence of sire and dam in the production of offspring. From the limited data collected various conclusions have been drawn, but as yet there is needed more accurate information before the problem will have been solved.

An effort to study this problem meets with many difficulties. Among them are: the lack of accurate and satisfactory units of character measurement; the lack of records of performance and development; no assurance of complete development of individuals concerned; insufficient numbers to make conclusions safe; lack of information concerning complete population; and doubtless others.

To these difficulties, others have been added in case of domestic animals, viz: length of generations and comparatively small number of individuals produced. The collection of data in this connection, for a study of this specific problem has been costly and slow. These reasons may in a measure account for the meagreness of data available.

In view of these facts it will readily be seen that any records concerning large numbers of individuals which have been preserved for a period of years should be thoroughly studied before being discarded. In only a few cases have Live Stock Breed Associations preserved data which could under any circumstance be used.

The Advanced Registry, or Registry of Merit, established in recent years by some of the Dairy Cattle Breed Associations have published data which may have some bearing upon the subject. Some work, which will be referred to later in this treatise, has been done with these data.

The American Trotting Horse Association has published since the year 1892 its annual volume known as Wallace's Year Book. These volumes contain lists of horses which have made a record for a mile of two minutes and thirty seconds (2:30) or better trotting, or two minutes and twenty-five seconds (2:25) or better pacing.

The chief reasons for presenting these particular data in a study of heredity are: that the records of the Standardbred horses are the most easily made available; that most phenomenal improvement has been made in this breed; and that with over 60,000 Standardbred horses with

records of 2:30 or better at the trot, and 2:25 at the pace, very little work of this nature has been done. Millions of dollars are invested in this breed of animals, yet only meagre data have been presented on the inheritance of the one characteristic for which the breed is produced -speed.

During the past century the record time for traveling a mile for the trotting horse has been lowered from 3:00 flat to 1:58. This increase in speed can be attributed to three (3) things, viz: improvement in equipment; improvement in methods; selection and breeding. It is stated that light sulkies with pneumatic tires have made possible an increase of five seconds. In the first part of the last century, the factor of great endurance was of importance, for at that time horses were raced for several miles. This practice was discarded in the early 50's and the mile was adopted as the standard distance. The effects of the change are not noticable, for a gradual and almost uniform rate of increase in speed is seen from the 3:00 mark up to the time and since the mile became the standard. Other improvements in methods used, such as, early and continual training; mechanical devices for correcting the error of equilibrium ; and such, have no doubt, played a greater part in

reducing the records than either the light sulkies or the mile track, yet some considerable part of the improvement of the trotting horse must be attributed to breeding and selection for speed.

Material on the relative influence of sire and dam upon the transmission of speed was easily obtained, but in most cases it was opinion rather than reliable data. Breeders of Standardbred horses passed different opinions as to the method by which speed is transmitted. Horses with low records have been sought and used as sires, some holding that the sire is of greater influence in the transmission of speed, others advocating their use because of the general law that like produces like. In other instances practical race-horse breeders state that speed in the dam is of more importance than speed in the sire, because of an opinion that it is transmitted to a greater extent through the dam than the sire. Very little is definitely known and the element of chance has entered prominently into the production of fast horses.

This work then is presented in an attempt to throw some light upon the relative importance of the sire and dam in the production of trotting horses with

records of 2:30 or better, and pacing horses with records of 2:25 or better. It is also hoped that it will show whether or not there is any correlation between the speed of the get and the speed of the sire or the speed of the dam, and if so, in which respect the correlation is the greater.

II. REVIEW OF LITERATURE

A review of work done on the relative influence of sire and dam upon the offspring reveals the fact that several attempts have been made, with different classes of animals, to show definitely which parent exerts the greater influence on offspring. Many of these investigations are based upon the records of one herd alone; others on a few exceptional animals from several herds; some from records published by Breed Associations. These are of little value to the practical breeder in solving the problems that confront him.

Very little work has been done on this specific problem. It is not surprising that little work has been done in the study of the laws of heredity of trotting

horses by experimental breeders, for the time element is so important in such work and a life time would be occupied with such an experiment. On the other hand, it is somewhat singular that greater use of the statistics found in Wallace's Year Book has not been made for studies in heredity.

The use of these records for a study of the laws of heredity was suggested by Frances Galton¹ in a paper read before the Royal Society of London, in 1897, but so far as the writer is able to ascertain, no use of these particular data have been made for studies of the laws of heredity up to date.

Attention has recently been called to the valuable data for heredity studies found in the Year Books by F. R. Marshall,² U. S. Department of Agriculture, Washington, D. C.

As very little work was available on the manner of inheritance of the functioning characteristics in a trotting horse, a review of the literature on the relative influence of sire and dam on the inheritance of analogous characteristics in other domestic animals was made.

1. Proceeding of the Royal Society. Vol. 62, page 310.

2. Journal of Heredity. Vol. V, No. 10, page 437.

Perhaps the most interesting and complete experimental work relating to the inheritance of functioning characteristics, that may have a direct bearing on this work, is that of Dr. Raymond Pearl¹ of the Maine Agricultural Experiment Station. These investigations were concerning the inheritance of fecundity in domestic fowls.

Two pens of pullets were used. The pullets of each pen were alike in every respect, as nearly as it was possible to get them, except that the dams of those in one pen were hens that produced 200 or more eggs during their pullet year, while the dams of those in the other pen were hens that produced less than 200 eggs during their pullet year. Each pen was fed and handled in the same manner. "Registered" cockerels (those whose dams produced 200 or more eggs during their pullet year) were used on each pen.

In comparing the egg yield of the mothers and daughters of the 200 egg group, the following conclusions were drawn: "The daughters of the 200 - egg producing mothers, although kept under substantially the same conditions and treated in the same manner as the mothers, are markedly inferior in winter and spring egg production."

1. Main Bulletin 166 (1909)

The author points out the fact that there is no evidence of correlation between the mother's and daughter's egg production. The pullets whose dams were producers of less than 200 eggs during their pullet year produced practically as many eggs during the experiment as those out of superior dams. "In other words", Dr. Pearl stated, "the data so far obtained do not indicate that egg producing ability is sensibly or directly inherited between mother and daughter."

Other work¹ of Dr. Pearl on, "Mode of Inheritance of Fecundity in Domestic Fowls", is of interest here. This is really a continuation and more detailed study of the subject mentioned above. Dr. Pearl states² that this work is beneficial to breeders of all live stock for the indications are that the functioning characteristics in other animals follow similar lines of inheritance as egg production.

The general results of this experiment are:

1. "High fecundity may be inherited by daughters from their sires, independent of the dam".
2. "High fecundity is not inherited by daughters from their dams".

1. Maine Bulletin 205, 1912.

2. Breeders Gazette, Vol. LXIV, No. 25, page 1279.

3. "Low degree of fecundity may be inherited by daughters from either sire or dam or both".

Probably more work has been done on the relative influence of sire and dam upon the functioning characteristics in dairy cattle than any other class of animals. The result of this work has been that various conclusions have been drawn. There was no way of determining which of these conclusions were the most reliable, as all were based on dependable data, so the following widely differing results were reviewed.

The first attempt¹ to find the manner in which milk yield was inherited in dairy cattle was made from the records of the Red Danish Herdbook.²

In these volumes only the best cows were listed. In view of this fact very few extremely low records were found. The data were limited in amount, but after tabulating and correcting as carefully as possible, by a system described by the author quoted above but too lengthy to give here, it was found that Danish cattle were classified roughly into three grades, viz: those yielding 5,000 pounds of milk, those yielding 7,000-8,000 of milk, and those yielding 10,000 pounds of milk, in a normal period of lactation. It was also found that the highest producing cows were the daughters of dams of their own or the middle class, and not of the lowest

1. The Principles of Stock-Breeding - Wilson, page 111.

2. Kostambogkoer af rod dansk Milkerace.
(The original could not be produced.)

class , and also that the bulls represented in the list were, as shown by their progeny, of the highest and the middle class. Mr. Wilson¹ draws the following conclusion from these facts: "The numbers, as a whole, were not large, but they were sufficiently so to suggest that milk yield was inherited in the same manner as Shorthorn colours." Mr. Wilson gives no explanation of how Shorthorn colours are inherited.

The next proposition before the investigator was to prove that this suggestion was a fact. This was done by working over a large herd of cattle in which records had been kept for a number of years. In this herd five bulls were used on all classes of cows and left a large number of heifer calves, whose records after the first calving were available. These divided themselves into the following classes:

1. Loc. cit. page 112.

	High Grade Cows — Producing 30-40 pounds of milk per day	Medium Grade Cows — Producing 20-30 pounds of milk per day	Low Grade Cows — Producing 13-20 pounds of milk per day
Daughters of Bull No.1	8	10	0
Daughters of Bull No.2	0	18	10
Daughters of Bull No.3	6	24	4
Daughters of Bull No. 4	4	11	7
Daughters of Bull No. 5	3	14	16

"Thus the suggestion that milk production is inherited in the same manner as color of Andalusian fowls or of Shorthorn cattle is confirmed". This conclusion drawn by Mr. Wilson is based on the fact that bull No. 1 got no low grade, and bull No. 2 no high grade daughters. Further confirmation must be had to prove definitely that the inheritance of milking qualities is a blend between sire and dam, yet these data are of importance as it is one authentic case which indicates such method of inheritance.

Peters¹ reports an investigation in the study of method of inheritance of milking capacity in cows, taken from the records of the registered herds of cows in East Prussia. The data showed a great variation in the inheritance of milk yield. In general, the offspring of the high producing cows were higher producers than those of the inferior dams. Superior dams produced good and inferior offspring, and vice versa. The inheritance varied around a center which was higher for the daughters of the high producing dams. This degree of variation was the same for all classes.

An investigation was then made of the production of the grand sire and grandams of the families in the herd.

1. Deutsche Landwirtschaftliche Tierzucht, Hanover, Germany, 1913. (The original could not be obtained. Taken from Journal of Her. Vol. 4. No. 1, page 18.)

This resulted in finding that some families produced relatively many good animals, while the descendants of others were usually inferior cows. In other families the author observed the usual wide variation in performance of offspring.

The editor of the Journal of Heredity¹ reviews the work as follows:

"The writer comes to the conclusion that it is not sufficient to estimate the absolute and relative yield of cows, and upon these data to select the offspring of the best individual performer for further breeding, but it is necessary to select the best families, for among the descendants of these will be found the largest number of good milk cows".

Marshall,² in a discussion of data collected from the Blue Book of the Holstein-Friesian Association, shows that these records furnish no support to the idea that milking qualities are transmitted through males rather than females.

In volume 10 of that series, there were found 1317 individuals with Advanced Registry records, whose paternal grandams also had an Advanced Registry record. In addition there were 687 instances in which the Advanced Registry individual had a maternal grandam within the Advanced Registry.

1. (loc. cit:)

2. (loc. cit:)

The difficulty of variation of age was overcome by selecting individuals from each the paternal and maternal sets that were of about the same age. When this selection was made there were 625 individuals in each list.

The coefficient of correlation of each group is shown below.

Summary of Results

Pounds of Milk Through Sires

	M	Em	σ	EO	r	Er
Granddaughters ...	370.6	± 2.29	88.5	± 1.67	-0.05	± 0.025
Grandams	475.3	± 2.56	98.7	± 1.95	-0.05	± 0.025

Through Dams

Granddaughters ...	393.4	± 2.63	99.5	± 1.95	-0.012	± 0.02
Grandams	437.4	± 2.09	80.8	± 1.54		

Pounds of Butter-fat Through Sires

Granddaughters ...	12.68	± 0.089	3.41	± 0.062	-0.04	± 0.025
Grandams	16.93	± 0.108	4.14	± 0.076		

Through Dams

Granddaughters ..	14.00	± 0.101	3.97	± 0.07	0.06	± 0.026
Grandams	15.83	± 0.087	3.31	± 0.06		

Percentage of Butter-fat
Through Sires

	M	Em	σ	E σ	r	Er
Grandaughters ...	3.47	± 0.009	$\pm .432$	± 0.008	0.107	± 0.02
Grandams	3.57	± 0.011	$\pm .448$	± 0.008		

Through Dams

Grandaughters ...	3.55	± 0.011	$\pm .445$	± 0.008	0.213	± 0.02
Grandams	3.50	± 0.013	$\pm .488$	± 0.009		

Taking the pair of individuals, that is one of "maternal grandam line" and one of "paternal grandam line", as they came in the classification, the following shows the number of cases found resembling maternal and paternal side:

	No. of cases in which the resem- blance was closest on maternal side	No. of cases in which resem- blance was closest on Paternal side
Pounds of Milk	403	262
Pounds of Butter-Fat	407	258
Percent of Butter-Fat	345	320

"In the two sets of cases already discussed there was a smaller number of paternal than maternal grandams, due to the fact that cows have more granddaughters through their sons than through their daughters. This objection, and the further objection as to environmental influence upon total production, is removed in a further study relating entirely to percent of butter-fat."

In the second study 126 Advanced Registry cows with granddaughters, through both sons and daughters, in the Advanced Registry were taken. There were 340 individuals chosen from each paternal and maternal line of descent. Here also the ages of the granddaughter and grandams of one line of descent corresponded closely with those of the other line. The mean, standard of deviation, and coefficient of correlation in this case of common grandams were as follows:

Paternal Descent	M:%Fat	E	σ	E		
Granddaughters	3.52	$\pm .02$	.442	$\pm .01$	$\checkmark$	$\pm .157$
Grandams	3.51	$\pm .02$	.406	$\pm .01$	E	0.028

Maternal Descent						
Granddaughters	3.60	$\pm .02$	.489	$\pm .01$	$\checkmark$	$\pm .155$
Grandams	3.51	$\pm .02$	.406	$\pm .01$	E	$\pm .028$

Marshall concludes as follows:

"The difference between .155 and .157 does not indicate any difference between transmission of the character of percentage of butter-fat in milk through males or females. The impression to the contrary, held by some cattle breeders, is probably based upon specific instances in which the bull used was more strongly bred than were the cows with which he was mated and usually prepotent on that account."

"Among¹ breeders of dairy cattle we find a prevailing impression that males of the dairy breed, generally, are prepotent in the transmission of the characteristics of the female of their race."

Sedgwick² is quoted as stating "It is well known, for example that the supply of milk by cows is hereditarily influenced by the bulls rather than by the cows from which they are directly descended, and that the character of the secretion, as regards both quantity and quality of milk, is chiefly derived from the parental grandmother."

The following data³ collected by the Department of Dairy Husbandry, University of Missouri, indicates that the above is true and that the milking qualities of the female in dairy cattle is more strongly inherited through the sire than the dam.

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1. Leon J. Cole, Am. Breeders Magazine, Vol. IV, No. 3, page 160.
 2. Burdach, Traite de Physiologic, Vol. III, page 117, (Original not found.) Taken from Stock Breeding-Miles, page 231.
 3. Unpublished data collected by Department of Dairy Husbandry University of Mo., used by special permission of Professor C.H. Eckles.

No. of dams and daughters considered	Average pounds of milk pro- duced by dams of daughters considered	Average pounds of milk pro- duced by daugh- ters out of dams and by sires considered	Average pounds of milk pro- duced by all of daughters of sires considered
10	7857	5707	5530
10	6509	5654	5520
10	5549	5365	5114
9	5169	5496	5314
10	4859	4969	5257
10	5532	5460	5086
10	4070	4767	4828
10	3128	4905	5087

In the above table the dams are arranged in groups of ten, beginning with the ten highest producers in the herd and grading to the ten lowest producers found. The

daughters of any group are not sired by the same bull. The column containing the average yield of all daughters of the bulls represents an average of the average production of all the daughters of several bulls.

Reed¹ summarized a discussion of production records of daughter as compared with dam when the sire is considered, as follows:

1. "The production characteristics of the daughter are not transmitted alike from the dam and the sire.

2. "High or low production characteristics may be inherited from the sire independent of the dam.

3. "Superior milk producing characteristics are not necessarily inherited from the dam. "

4. "Variation in production is noticable to a greater or lesser degree in all sire groups."

Most authorities on animal breeding seem to be of the opinion that neither sire nor dam exert any predominant influence upon the offspring by the virtue of their sex. But that the "best-bred" parent, that is the parent containing the greater purity of the race, is prepotent. This fact has led many people to conclude that the sire exerts the greater influence upon the offspring, because the majority of the family resemble the male. The resemblance,

1. The Reliable Influence of Sire and Dam on Dairy characteristics of offspring - T. C. Reed, Thesis 1914, Department of Dairy Husbandry, University of Missouri.

in the light of this opinion, is due to the fact that the sire, in most cases, is the better bred and selected of the parents and not by the virtue of the sex.

Stonehinge¹ makes the following statement:

"My own belief in this matter founded upon observations made during a long series of years, on the horse as well as the dog, is, that no rule can be laid down with any certainty. Much depends upon the comparative physical power and strength of constitution of each parent - even more perhaps than the composition of the blood.

"There have been many instances of two brothers being used in the stud, both among horses and grey hounds, in which one has almost invariably got stock resembling himself in all particulars, not even excluding color, while the descendants of the other have rarely been recognized as his. Thus among horses the Touchstones have been mostly brown or dark bay, and as a lot, have shown a high form as race-horses: while the Launcelots have been of all colors, and have been below mediocrity on the turf. (Launcelot and Touchstone were full brothers).

"Now surely this difference in the power of transmitting the likeness of the sire, when the blood is exactly the same as it is observed to extend over large numbers, can

1. The Horse - Stonehinge, page 447.

only depend upon a variation in individual power. Not only does this apply to the males but the females also show the same difference."

No records of the mares that these two stallions were mated with were given and therefore no direct comparison should be made as to the relative influence of sire and dam. But the chances are that each of these stallions, since they were full brothers, were bred to mares of approximately the same average speed. Thus horses of the same breeding vary in ability to transmit their characteristics and "individual prepotency" is a great factor.

A. Weismann¹ explains this form of heredity in terms of the idioplasm. An "id" is used as an heredity unit in this explanation, and the carriers of these "ids" were called "idants". The dominating group of idants passes over from one parent-say male - to the germ plasm of the offspring and there meets a weaker group of idants from the other parent. The results will be that not all the inheritance of the offspring will be shaped by the idants of the male, but they will dominate the idants of the weaker group and the offspring will resemble the male parent.

1. The Germ-Plasm - Weismann, page 290.

III. CONSIDERATION OF DATA USED

There are two ways of studying the relative influence of parents on the offspring viz; by experimental breeding, and by use of records found in connection with the pedigrees of the parents and individuals. The former is successfully employed in investigations with animals where the time element is not important, as with mice, poultry and guinea-pigs, but the latter method must be resorted to when making investigations with animals that breed slowly, as horses and cattle.

While records are meagre, the publications best suited for such work are : the volumes of the Advanced Registry of the dairy breeds of cattle, and the records of the American Trotting-Horse Association - Wallace's Year Book.

Source of Data and Requirements Made of Each Individual Used.

The individuals used in these data were taken from the entries in Wallace's Year Book, volumes 25 - 29 inclusive, referring to the years of 1909-13. The following requirements were made of each individual used:

1. That it be a Standardbred trotter or pacer with a record of 2:30 or better at the trot or 2:25 or better at the pace, and that the age at which
-

this record was taken be knowh.

2. That it had for both sire and dam a Standardbred trotter or pacer with a record of 2:30 or better at the trot or 2:25 or better at the pace, and the age at which these records were taken be known.

3. That the record of individual, sire and dam must have been made in a public race and an official report of it made to the American Trotting Horse Association.

Method of Collecting Data.

In collecting the data cards were used, Fig.1. White cards were used for trotting and pink cards for pacing individuals. The records of the individuals were obtained from "Statistical Tables" No.I and II,- "Alphabetical List of 2:30 Trotters in Harness", and "Alphabetical List of 2:25 Pacers in Harness",- in volumes 25-29 of the Year Book. The records of the sires and dams were then found in the similar lists in the preceeding volumes.

Individual				Age when Record Was Made	Volume of Year Book	Record
		Gelding	Mare	Horse		
Sire						
			Pace	Trot		
Dam						
			Pace	Trot		

Figure No.I.

It was necessary to investigate the records of many individuals, and to eliminate all except those records made by individuals whose sires and dams also made records of 2:30 or better trotting or 2:25 or better pacing. Many were eliminated because the age at which the record of the sire or dam was taken could not be obtained. The lack of complete records of the Standardbred horses, that were used as sires and dams, is shown by the fact that out of 5,407 trotters and 3,284 pacers, that were raced and placed in the 2:30 or

2:25 list during the five seasons, 1909-1913, only 1,114 individuals could be found with pedigrees and records of foaling and performance sufficiently complete to be used in these data. Care was taken to exclude duplicates, and in case horses were listed as racing in two or more successive years the best record was taken and the others discarded. Thus each record used in these data is the best made by any specific horse.

Probable Error in Recording Records.

Some question has arisen as to the correctness of the fraction of a second. There is, no doubt in some cases, a tendency on the part of timekeepers to be biased towards certain numbers, or to give horses the advantage of the quarter second. Galton¹ shows that the quarter seconds are not reliable by the following method: He chose at random a few hundred entries from the Year Book and found that the relative frequency of 0, $1/4$, $1/2$ and $3/4$ was approximately 1,3,2 and 1. If absolute accuracy were observed in recording these fractions of a second they should be about equal in number. The quarter of a second may not be dependable yet the records may be depended upon as being accurate to the second.

1. loc. cit.

Limitations of Data Based on Records of this Nature.

Data which includes only the best individuals of a population are limited in their use and general conclusions can be drawn from such data only in a few cases. These data are presented with a knowledge of this limitation, and this fact will be considered in conclusions that are drawn.

Classifications of all Individuals Used.

After the data were collected the cards were arranged according to the following classification:

I. Trotting individuals sired by trotting stallions out of trotting mares.

II. Trotting individuals sired by trotting stallions out of pacing mares.

III. Trotting individuals sired by pacing stallions out of trotting mares.

IV. Trotting individuals sired by pacing stallions out of pacing mares.

V. Pacing individuals sired by trotting stallions out of trotting mares.

VI. Pacing individuals sired by trotting stallions out of pacing mares.

VII. Pacing individuals sired by pacing stallions out of trotting mares.

VIII. Pacing individuals sired by pacing stallions out of pacing mares.

These were then classified with reference to age at which record was made, and tabulated as shown in the following tables.

The average record, average age which record was made, etc., is given for each, the stallions, mares and geldings, and an average of these averages is made which gives an average for all classes of horses.

Explanation of Curves and Tables.

A graphical representation of each table is presented just following the table. The plate and table numbers correspond. Each plate is divided into three parts by heavy black lines. The upper third is used for the curves of the average speed of stallions and their sires and dams, the middle for the average speed of mares and their sires and dams, and the lower part for the average speed of the geldings and their sires and dams. At the top of the page the figures, 5, 6, 7, 8, 9, 10 and 11 show the age at which record was made for all three classes. At the lower part of each section allotted to the stallions, mares and geldings and directly under the figures which represent the age at which the record was made are the numbers of the individuals used in obtaining the average record for this age. Each space in the abscissa represents a second and each ten spaces in the ordinate represents a year.

Table No. 1. Trotting Individuals Sired by Trotting Stallion of 3rd Trotting Series.

Individuals		Class		Average		Imp. Rec.		Imp. Rec.		Imp. Rec.		Imp. Rec.	
No.	Class	Records	at yr.	Records	at yr.	Records	at yr.	Records	at yr.	Records	at yr.	Records	at yr.
38	Stallion	2:25.01	2	2:11.11	4.00	13.5	2:20.00	5.10	2:20.00	5.10	2:20.00	5.10	2:20.00
54	Mare	2:24.4	2	2:11.45	5.00	13.5	2:20.00	5.07	2:20.00	5.07	2:20.00	5.07	2:20.00
92	both	2:24.9	3	2:11.72	5.00	15.15	2:20.01	5.00	2:20.01	5.00	2:20.01	5.00	2:20.01
47	Stallion	2:24.11	3	2:12.04	5.00	11.55	2:19.07	5.05	2:19.07	5.05	2:19.07	5.05	2:19.07
62	Mare	2:24.05	3	2:12.07	5.01	11.21	2:19.40	5.07	2:19.40	5.07	2:19.40	5.07	2:19.40
7	Gelding	2:24.21	3	2:15.43	7.00	6.70	2:20.00	5.14	2:20.00	5.14	2:20.00	5.14	2:20.00
116	All	2:24.08		2:12.70	5.91	11.25	2:19.27	5.00	2:19.27	5.00	2:19.27	5.00	2:19.27
26	Stallion	2:21.52	4	2:11.04	5.70	10.40	2:21.04	5.00	2:21.04	5.00	2:21.04	5.00	2:21.04
36	Mare	2:21.23	4	2:14.13	5.77	7.04	2:20.00	5.00	2:20.00	5.00	2:20.00	5.00	2:20.00
6	Gelding	2:24.08	4	2:15.23	6.16	6.92	2:24.70	5.00	2:24.70	5.00	2:24.70	5.00	2:24.70
68	All	2:21.06		2:13.07	5.77	8.52	2:21.53	4.07	2:21.53	4.07	2:21.53	4.07	2:21.53
32	Stallion	2:17.14	5	2:11.20	7.12	5.94	2:20.60	5.00	2:20.60	5.00	2:20.60	5.00	2:20.60
64	Mares	2:19.84	5	2:13.70	6.10	6.17	2:21.15	5.00	2:21.15	5.00	2:21.15	5.00	2:21.15
14	Geldings	2:22.51	5	2:14.14	5.21	8.22	2:21.19	5.00	2:21.19	5.00	2:21.19	5.00	2:21.19
112	All	2:19.39		2:12.80	6.10	6.26	2:20.61	5.01	2:20.61	5.01	2:20.61	5.01	2:20.61
19	Stallions	2:18.10	6	2:11.44	5.42	5.06	2:19.08	5.00	2:19.08	5.00	2:19.08	5.00	2:19.08
36	Mares	2:18.06	6	2:12.58	6.44	5.68	2:20.00	5.00	2:20.00	5.00	2:20.00	5.00	2:20.00
25	Geldings	2:19.09	6	2:16.97	6.20	2.11	2:19.03	6.72	2:19.03	6.72	2:19.03	6.72	2:19.03
80	All	2:18.51		2:13.72	6.12	4.15	2:19.57	5.00	2:19.57	5.00	2:19.57	5.00	2:19.57

Continued on next page.

Plate No.1, Trotting Individuals sired by Trotting Stallions out of Trotting Mares.

Table No. 11. Trotting Individuals sired by Trotting Stallions out of Pacing Mares.

Individuals				Sire				Dam			
No.	Class	Average	Record	Age	Av. age	Av. sec. dif-	Av. age	Av. sec. dif-	When re-	cord was	from indi-
used	of an-	Records.	taken	Records	Records	ference	Records	ference	made	made	vidual.
in av.	imals.	at yr.	at yr.	cord was	cord was	from indi-	cord was	from indi-	made	made	vidual.
2	Stallion	2:28.00	2	2:11.25	4.50	16.75	2:17.00	5.50	11.00		
8	Mare	2:27.85	2	2:10.81	4.62	16.84	2:14.32	5.75	13.47		
10	Both	2:27.88		2:10.90	4.59	16.82	2:14.77	5.70	12.97		
6	Stallion	2:23.62	3	2:15.25	4.85	6.71	2:14.96	6.33	7.00		
6	Mare	2:25.96	3	2:14.66	5.90	11.49	2:16.29	7.40	9.66		
12	Both	2:24.76		2:14.85	5.36	9.00	2:15.62	6.86	8.33		
3	Stallion	2:23.25	4	2:14.33	5.00	8.91	2:22.16	5.00	1.11		
6	Mare	2:23.88	4	2:16.16	5.50	5.75	2:16.39	7.50	7.00		
9	Both	2:23.47		2:15.55	5.33	6.80	2:18.44	6.60	5.03		
1	Stallion	2:11.50	5	2:08.00	7.00	3.50	2:14.00	6.00	-2.50		
10	Mare	2:21.72	5	2:11.82	5.90	9.90	2:15.20	6.00	6.60		
2	Gelding	2:25.25	5	2:22.37	8.50	2.88	2:16.62	4.50	8.62		
13	All	2:21.50		2:13.10	6.38	8.32	2:15.32	5.76	6.28		
3	Stallion	2:17.50	6	2:16.58	7.30	.91	2:17.83	3.66	- .42		
9	Mare	2:20.25	6	2:17.11	5.10	3.00	2:17.64	7.10	2.49		
2	Gelding	2:19.25	6	2:20.37	4.50	-1.00	2:19.50	5.50	- .12		
14	All	2:19.51		2:17.46	4.77	1.96	2:17.94	6.12	1.49		

Continued on next page.

Table No. II Continued. Trotting Individuals sired by Trotting Stallions out of Racing Mares

Individuals

No. used in av.	Class	Average records.	Record taken at yrs.	Sire			Dam		
				Average	av. age	av. rec. dif-ference	average	av. age	av. rec. dif-ference
				Records.	when re-cord was made	from indi-viduals	Records.	when re-cord was made	from indi-vidual.
5	Stallion	2:20.24	7	2:10.95	5.00	11.45	2:15.32	7.30	5.25
9	Mare	2:22.35	7	2:13.77	7.20	5.48	2:19.00	7.77	5.24
4	Gelding	2:22.56	7	2:19.00	5.25	3.56	2:11.75	7.00	10.81
18	All	2:21.75		2:13.87	6.15	6.15	2:13.36	7.44	5.48
1	Stallion	2:23.25	8	2:15.50	3.00	13.75	2:19.50	11.00	9.75
2	Mare	2:20.87	8	2:26.75	7.00	-5.87	2:22.00	6.50	-1.12
2	Gelding	2:21.00	8	2:15.87	6.00	5.13	2:19.12	5.00	1.88
5	All	2:22.59		2:20.15	5.80	2.45	2:20.35	6.80	2.25
1	Stallion	2:14.25	9	2:28.25	3.00	-14.00	2:17.25	12.00	2.00
1	Mare	2:18.25	9	2:12.00	3.00	6.25	2:23.00	3.00	-4.75
2	Gelding	2:16.12	9	2:18.50	4.50	-2.37	2:16.87	9.00	- .75
4	All	2:16.18		2:19.31	3.75	-3.12	2:18.49	5.75	-1.08
3	Stallion	2:22.33	10	2:19.66	6.66	2.67	2:19.08	7.66	3.25
1	Mare	2:21.50	10	2:13.50	8.00	8.00	2:23.00	6.00	-1.50
4	Both	2:21.87		2:18.12	6.99	4.00	2:20.08	7.19	2.08
2	Mare	2:20.25	11	2:09.12	6.50	11.00	2:17.75	5.50	2.50
1	Stallion	2:27.75	12	2:16.00	6.00	11.75	2:10.25	9.00	17.50
1	Gelding	2:08.25	12	2:15.50	3.00	-7.25	2:12.25	5.00	-4.00
2	Both	2:18.00		2:15.75	4.50	4.50	2:11.25	7.00	3.50

Total Number of Individuals in Table No. II - 94.

Plate No. II, Trotting Individuals sired by Trotting Stallions out of Pacing Mares.

Table No. III. Trotting Individuals Sired by Facing Stallions out of Trotting Mares.

Individuals				Sire			Dam		
No.	Class	Average	Record	Average	Av. age	Av. sec. dif-	Average	Av. age	Av. sec. dif-
used	of an-	Records	taken	Records	when re-	ference	Records	when re-	ference
in av.	in is	at pre.	at pre.	cord was	cord was	from in-	cord was	cord was	from in-
				individual.	individual.	dividual.	individual.	individual.	dividual.
				Mare	Mare		Mare	Mare	
2	Mare	2:21.75	2	2:07.75	4.0	14.00	2:22.77	4	-1.13
2	Stallion	2:24.25	3	2:12.75	6.5	11.50	2:20.87	4	3.38
3	Mare	2:26.27	3	2:03.41	6.3	23.33	2:27.91	5.3	-1.17
5	All	2:25.49		2:07.15	7.6	18.59	2:23.09	4.0	- .05
1	Stallion	2:18.50	4	2:07.75	4.0	10.75	2:17.00	6.0	1.50
1	Mare	2:17.25	4	2:11.25	7.0	6.00	2:25.00	5.0	-7.75
2	All	2:17.87		2:09.50	5.5	8.37	2:21.00	5.5	3.12
1	Stallion	2:25.25	5	2:07.50	12.0	17.75	2:16.25	7.0	9.00
5	Mare	2:24.15	5	2:16.95	5.4	7.00	2:26.65	6.6	-2.30
1	Gelding	2:23.25	5	2:10.25	5.0	13.25	2:19.25	5.0	4.25
7	All	2:24.18		2:14.65	6.00	9.57	2:24.10	6.43	.25
2	Stallion	2:17.75	6	2:11.00	8.5	6.75	2:20.50	7.5	-2.75
2	Mare	2:18.25	6	2:14.00	5.5	4.25	2:27.25	6.5	-9.00
2	Gelding	2:21.37	6	2:08.87	9.0	12.50	2:21.25	5.0	.12
6	All	2:19.12		2:11.29	7.6	7.83	2:23.00	6.3	-3.88

Continued on next page.

Table No. III Continued. Trotting Individuals Sired by Racing Stallions out of Trotting Mares

Individuals		Sire				Dam			
No.	Class	Average	Record	Average	Av. sec. dif-	Average	Av. age	Av. sec. dif-	
used	of an-	Records.	taken	Records	ference from	Records	When re-	ference	
in av.	inals		at yrs.		individual.		cord was	from in-	
							made	dividual	
3	Mare	2:22.33	7	2:13.50	6.3	8.83	2:20.16	6.66	2.20
3	Gelding	2:21.41	7	2:10.50	6.3	10.91	2:26.08	5.33	-4.66
6	All	2:21.87		2:12.00	6.3	9.87	2:23.12	6.00	-1.23
4	Stallion	2:11.25	8	2:19.75	7.0	-8.50	2:27.25	5.00	-16.00
6	Mare	2:22.70	8	2:05.08	5.83	17.46	2:19.37	4.83	3.16
1	Gelding	2:17.50	8	2:06.75	9.00	10.75	2:24.75	6.00	-7.25
8	All	2:20.06		2:07.07	6.37	13.37	2:21.03	4.98	-4.28
1	Mare	2:23.25	9	2:19.25	9.00	4.00	2:22.50	7.00	.75
1	Gelding	2:28.25	9	2:09.75	7.00	17.50	2:20.25	10.00	8.00
2	Both	2:25.75		2:14.50	8.00	10.75	2:21.37	8.50	4.37
1	Mare	2:16.25	10	2:17.25	4.00	-1.00	2:29.25	4.00	-13.00
1	Mare	2:14.50	11	2:08.75	5.00	5.50	2:13.50	9.00	1.00

Total Number of Individuals in Table No. III-40.

Plate No. III. Trotting Individuals sired by Pacing Stallions out of Trotting Mares.

Table No. IV. Trotting Individuals sired by Pacing Stallions out of Pacing Mares.

Individuals			Sire			Dam		
No. used in av.	Class of animals.	Average Record.	Record taken at yrs.	Average records.	Av. age when record was made.	Av. sec. diff. of distance from individual.	Av. age when record was made.	Av. sec. diff. of distance from individual.
2	Mare	2:24.52	2	2:03.75	9	15.87	2:13.15	3.5
1	Stallion	2:29.50	3	2:17.25	5	13.25	2:17.25	7.0
1	Mare	2:25.25	4	1:55.25	9	23.00	2:13.25	7.0
1	Mare	2:20.25	5	2:05.50	3	14.75	2:09.50	5.0
2	Mare	2:23.25	6	2:12.50	4.5	10.75	2:14.25	6.5
2	Mare	2:18.25	7	2:11.50	6.5	6.25	2:13.25	6.5
1	Mare	2:24.50	12	2:14.50	7	10.00	2:15.25	7.0

Total no. of Individuals in Table No. IV.-10

Table No. V. Facing Individuals sired by Trotting Stallions out of Trotting Mares.

Individual				Sire				Dam			
No. used in av.	Class of animals	Average Records.	Record taken at yrs.	Average Records.	av. age when record was made	av. sec. difference from individual.	Average Records.	av. age when record was made.	av. sec. difference from individual.		
4	Stallion	2:16.97	7	2:10.50	6.75	0.86	2:19.67	5.35	-2.61		
6	Mare	2:15.03	7	2:12.64	5.00	0.56	2:22.16	6.10	-7.14		
4	Gelding	2:14.00	7	2:15.44	8.00	-1.43	2:13.75	6.23	.34		
14	All	2:15.26		2:13.54	6.61	1.42	2:19.04	5.90	-0.80		
7	Stallion	2:11.60	8	2:12.71	6.42	-1.10	2:22.14	5.14	-10.59		
6	Mare	2:16.12	8	2:13.04	6.53	3.29	2:20.33	6.00	-4.21		
13	Both	2:13.66		2:12.86	6.40	.92	2:21.30	5.53	-7.59		
2	Stallion	2:10.25	9	2:11.37	7.00	-1.12	2:24.37	6.00	-14.12		
3	Mare	2:16.58	9	2:14.00	4.66	2.75	2:19.75	6.00	-3.16		
2	Gelding	2:21.25	9	2:15.12	8.50	6.12	2:24.75	4.50	-5.50		
7	All	2:16.10		2:13.57	6.42	4.03	2:22.49	5.59	-6.59		
4	Stallion	2:12.19	10	2:06.06	5.00	6.12	2:20.81	7.75	-8.63		
3	Mare	2:18.00	10	2:14.41	5.33	3.58	2:13.25	6.00	2.75		
1	Gelding	2:23.25	10	2:25.25	6.00	-2.00	2:19.25	5.00	4.00		
8	All	2:15.62		2:11.30	5.25	4.15	2:18.53	6.75	-2.78		
2	Stallion	2:20.12	11	2:11.87	7.50	8.25	2:19.37	8.50	.225		
2	Gelding	2:10.25	11	2:14.75	5.00	-4.50	2:27.25	6.50	-17.00		
4	Both	2:15.18		2:13.31	6.25	1.87	2:25.56	7.50	-8.34		
1	Stallion	2:21.25	12	2:19.00	5.00	2.50	2:20.25	10.00	1.25		

Total number of individuals in Table No. V - 110.

Plate No.V. Pacing Individuals sired by Trotting Stallions out of Trotting Mares.

Table No. VI. Pacing Individuals sired by Trotting Stallions out of Pacing Mares.

Individual			Sire			Dam		
No.	Class	Average	Record	Average	Age	Av. sec. dif-	Av. sec. dif-	
used	of an-	Records	taken	Records	when re-	ference from	Records	when re-
in av.	imals.	et yrs.			cord was:	individual.	cord was:	from indi-
					made.		made	vidual.
1	Stallion	2:24.25	3	2:15.75	3.00	8.50	2:22.50	5.00
2	Mare	2:22.75	3	2:07.55	7.00	15.37	2:17.12	7.00
1	Gelding	2:25.00	3	2:04.25	8.00	20.50	2:14.75	7.00
4	All	2:23.69		2:08.67	6.25	14.93	2:17.87	6.50
4	Stallion	2:21.81	4	2:19.45	8.00	2.37	2:20.31	7.00
5	Mare	2:16.45	4	2:15.84	5.40	.60	2:13.65	6.40
2	Gelding	2:20.12	4	2:17.75	4.00	2.37	2:11.75	7.50
11	All	2:20.17		2:17.49	6.09	1.56	2:15.56	5.90
4	Stallion	2:18.50	5	2:19.62	5.50	-1.13	2:19.18	6.00
9	Mare	2:18.66	5	2:19.16	5.66	-.47	2:15.75	5.44
6	Gelding	2:16.33	5	2:17.04	8.00	-.50	2:13.41	7.50
19	All	2:17.94		2:18.56	6.37	-.62	2:15.73	6.10
5	Stallion	2:19.45	6	2:13.00	6.40	6.45	2:11.65	6.60
9	Mare	2:15.00	6	2:15.97	6.30	-.97	2:17.91	6.00
2	Gelding	2:14.37	6	2:10.75	4.50	3.62	2:15.37	6.00
16	All	2:16.25		2:14.39	6.10	1.92	2:15.63	6.18
								.67

Continued on next page.

Table No. VI. Continued. Pacing Individuals sired by Trotting Stallions out of Pacing Mares.

Individual				Sire				Dam			
No. used in av.	Class of animals.	Average Record taken at yrs.	Average Records.	av. age when record was made.	av. sec. dif-ference from individual.	Average Records.	av. age when record was made.	av. sec. dif-ference from individual.			
3	Stallion	2:16.25	7	2:23.83	6.30	-7.58	2:19.08	7.30	-3.83		
9	Mare	2:18.30	7	2:15.09	8.10	-2.61	2:15.90	5.80	2.39		
5	Gelding	2:17.75	7	2:17.70	4.00	.05	2:19.05	5.20	-1.50		
17	All	2:21.37		2:17.71	3.51	0.00	2:17.33	7.06	.38		
5	Stallion	2:15.25	8	2:13.90	7.00	1.45	2:19.10	5.00	-3.85		
4	Mare	2:16.41	8	2:19.56	5.25	-3.25	2:16.08	6.00	.25		
4	Gelding	2:16.62	8	2:17.50	5.75	-.94	2:15.70	6.25	.77		
13	All	2:15.95		2:16.82	6.00	-.29	2:17.11	5.92	-1.16		
2	Stallion	2:17.75	9	2:19.00	7.00	-1.25	2:10.37	7.50	7.37		
3	Mare	2:17.66	9	2:21.00	4.00	-3.12	2:22.75	5.66	-4.31		
5	Both	2:17.69	9	2:20.50	5.20	-2.93	2:17.79	6.39	.18		

Total number of Individuals in Table No. VI - 85

Plate No. VI. Pacing Individuals sired by Trotting Stallions out of Pacing Mares.

Table NO.VII. Racing Individuals Sired by Racing Stallions out of Trotting Sires.

Individuals			Sire			Dam			
No. used in av.	Class of animals.	Average record : Records taken at av.	Average : when record was made	av. age : when record was made	Average : when record was made	av. age : when record was made	Average : when record was made	av. age : when record was made	
1	Stallion	2:24.50	2	1:55.25	9	29.35	2:27.25	5	-2.75
2	Mare	2:22.75	2	2:01.25	8	21.50	2:23.52	5	-1.13
3	Both	2:23.53		1:59.25	0.03	24.08	2:24.83	5	-1.64
1	Stallion	2:15.25	3	2:03.25	6	12.00	2:23.25	8	-7.00
2	Stallion	2:22.75	4	2:04.37	4.5	18.37	2:28.53	4.5	-7.87
1	Gelding	2:17.50	4	2:09.75	5.0	7.75	2:18.25	5	- .75
3	Both	2:20.83		2:06.17	4.56	14.84	2:25.16	4.56	-5.49
4	Stallion	2:16.00	5	2:09.87	5.5	6.12	2:22.50	4.5	-6.50
6	Mare	2:17.79	5	2:07.91	5.56	10.04	2:24.37	5.0	-6.58
2	Gelding	2:18.25	5	2:05.50	7.5	12.75	2:16.50	5.0	1.25
12	All	2:17.35		2:08.24	5.91	9.18	2:22.43	5.5	-5.25
1	Mare	2:24.25	6	2:09.75	6.0	14.50	2:21.75	10.0	2.50
1	Gelding	2:12.50	6	2:10.25	5.0	2.25	2:19.25	5.0	-6.75
2	Both	2:18.37		2:10.00	5.5	6.37	2:20.50	7.5	-2.12

Continued on next page.

Table No. VII. Continued. Racing Individuals sired by racing stallions out of brooding mares.

Individuals			Sire			Dam		
No. used in av.	Class of animals	Average: record taken at year.	Average: av. age	iv. sec. diff. from records	iv. sec. diff. from records	iv. sec. diff. from records	iv. sec. diff. from records	iv. sec. diff. from records
4	Stallion	2:09.12	2:07.03	5.75	2.06	2:23.19	4.75	-14.00
3	Mare	2:17.56	2:08.42	7.33	9.16	2:23.00	5.0	-15.42
2	Gelding	2:08.75	2:09.37	5.00	- .63	2:23.97	9.50	-15.12
9	All	2:11.68	2:08.02	6.11	3.83	2:23.39	5.9	-11.41
4	Stallion	2:10.06	2:14.50	6.00	-4.44	2:27.44	6.5	-17.37
1	Mare	2:19.25	2:00.50	7.00	18.75	2:08.25	4.0	11.00
2	Gelding	2:18.25	2:10.12	9.00	8.12	2:26.37	6.0	- 8.12
7	All	2:13.71	2:11.25	7.00	2.46	2:24.37	6.0	-10.67
1	Stallion	2:17.25	2:05.75	9.00	11.50	2:24.25	8.0	- 7.00
1	Gelding	2:09.75	2:17.75	11.0	-7.50	2:26.25	3.0	-15.50
2	Both	2:13.50	2:11.75	10.0	2.00	2:25.25	5.5	- 6.25
2	Stallion	2:16.25	2:12.00	7.00	-3.25	2:20.00	7.0	- 4.25
1	Stallion	2:14.50	2:03.25	6.00	11.25	2:11.50	6.0	3.00
1	Mare	2:17.25	2:11.25	6.0	6.00	2:14.25	7.0	3.00
1	Mare	2:19.75	2:14.25	6.50	5.5	2:17.50	11.0	2.25

Total No. of Individuals in Table No. VII-44

Plate No. VII. Pacing Individuals sired by Pacing Stallions out of Trotting Mares.

PLATE A - HURDLE OF THE UNIVERSITY CO-OPERATIVE STORE, COLUMBIA, MO.

DEPARTMENT OF ENGINEERING, UNIVERSITY OF MO.

Table No. VIII. Pacing Individuals sired by Pacing stallion out of Pacing mares.

[illegible]

Continued on next page.

Table NO. VIII Continued. Pacing Individuals sired by Pacing Stallions out of Pacing Mares.

Individuals			Sire			Dam		
No. used in av.	Class of animals.	Average of Records.	Record taken at yrs.	Average of Records.	Record taken at yrs.	Average of Records.	Record taken at yrs.	Average of Records.
15	Mare	2:18.35	6	2:10.42	4.90	7.95	2:13.84	6.4
7	Gelding	2:18.17	6	2:10.64	8.86	8.05	2:14.97	6.0
20	Both	2:18.49		2:10.49	5.58	7.87	2:14.33	6.26
5	Stallion	2:16.75	7	2:07.60	7.20	9.15	2:14.75	5.40
6	Mare	2:17.79	7	2:08.33	6.0	9.43	2:13.39	5.5
4	Gelding	2:15.00	7	2:08.00	7.5	7.00	2:13.31	7.25
15	All	2:16.69		2:07.99	6.8	8.68	2:13.51	5.90
8	Mare	2:15.25	8	2:10.59	6.1	4.66	2:13.97	5.25
2	Gelding	2:14.75	8	2:08.75	7.0	6.0	2:18.75	8.00
10	All	2:15.15		2:10.22	6.28	4.92	2:16.34	5.8
2	Stallion	2:11.00	9	2:10.50	5.0	.75	2:11.24	4.5
3	Gelding	2:18.41	9	2:12.33	7.66	6.08	2:18.90	6.0
5	Both	2:15.44		2:11.59	6.49	3.95	2:15.83	5.4
2	Mare	2:19.75	11	2:11.00	4.50	8.75	2:16.75	6.0

Total number of individuals in Table No. VIII-95

Plate No. VIII. Pacing Individuals sired by Pacing Stallions out of Pacing Mares.

IV RELATIVE INFLUENCE OF SIRE AND DAM ON ENTIRE SONS AND DAUGHTERS.

Derivation of Summaries Obtained.

In the tables, I-VIII, the arithmetical average of the records of the individuals was taken, the age at which record was made, and the difference from that of sires and dams. An arithmetical average of these classes was then taken for the final average of records, age and difference in records for all individuals of each class. In the final summary the word "all" is used to designate the average of all classes of animals, i.e. stallions, mares, geldings, while "both" is used when only two classes are used, as mares and geldings; stallions and mares, or stallions and geldings.

The average difference in seconds of sires' and dams' records from that of the individuals is given in a column under each list of sires and dams. The minus sign indicates that the average record of the sires or dams was slower than the average record of the individuals while the plus (not expressed but understood in all cases where minus is not inserted) indicates that the average record of the sires or dams was faster than the average record of the individuals by the number of seconds indicated.

Elimination of Tables on Account of
Insufficient Number of Individuals
to Give Representative Averages.

Results based on the average of several individuals are unreliable unless a sufficient number of individuals are included to make the average a representative one. No attempt is made here to estimate the number of individuals that would constitute a representative average, but it is evident that table No. II, Trotting Individuals sired by Pacing Stallions out of Trotting Mares, which contains the records of only 40 individuals, table No. IV, Trotting Individuals sired by Pacing Stallions out of Pacing Mares, which contains the records of only 10 individuals, and table No. VII, Pacing Individuals sired by Pacing Stallions out of Trotting mares, which contains the records of only 44 individuals, do not contain the records of a sufficient number of individuals to warrant conclusions. These tables have been given for the purpose of making complete the set, and for the value they may have for studying the offspring of all the various combinations of parentages. Conclusions from such small numbers as these are not safe. Therefore these tables are eliminated in all future discussions and only tables I, II, V, VI and VIII are used hereafter.

In this discussion the data contained in table No. I are used more frequently than any other. This table contains the records of 640 individuals, and approaches a representative average of this class of animals. Thus the conclusions made evident from this table are to be taken when conflicting with conclusions drawn from data in which a smaller number of individuals are represented.

Elimination of Immature Individuals

Table No. IX shows that those individuals that made their records before they were five years old had on the average, slower records than those individuals that made their record at five years of age and older. It also shows that there is a gradual decrease, in the classes where sufficient number of individuals were used to give a reliable average, from the average records of the two year old individuals to average records of the five year old individuals. Very little difference is noted in the average of records made by individuals from five to twelve years of age. In other words, the average records of all individuals used in these data seem to indicate that the trotting or pacing individuals, regardless of sex or parentage, reaches maturity at approximately five years of age.

In tables I-VIII it is noted that the "average age

when record was made" for sires and dams rarely is less than five nor exceeding six years, and the average age at which a record was made by all sires and dams included is slightly above five years. The fact that the trotting horse matures at about five years of age was considered by Galton in work done in 1897 in which he states ".... and who also had arrived at maturity, that is, who were not less than five years old, and therefore had had time to show their full powers"¹.

In view of the above facts, it was decided to discard all individuals that had made records at less than five years of age, retaining only those that made records at five years of age or older or that were mature when the record was made and had had ample opportunity to show their full powers. Therefore a line is drawn in each table to separate those used in the following discussion from those not used.

Discussion of Tables.

The average records of the individuals in each table indicates that there is practically no difference in the records of the different classes of animals during any year after maturity is reached, but before the animal is mature the geldings are, as a rule, two to four seconds slower

1. loc. cit.

than the stallions or mares. Since only the records of the mature--five years or older--horses are used in the following discussions the stallions, mares and geldings are considered on equal basis.

From table No.I it is observed that there is a variation of only 1.54 seconds in the average record of the individuals which made their records at five years of age and those that made records later in life. Thus there is very little difference in the average record of horses after five years of age. With the sires of these individuals the variation of the average speed is greater. The sires of those horses that made their record at five years of age have an average record of 2:12.8 while those whose get made their record at 10 years of age have an average record of 2:16.49. Here is a variation of 3.69 seconds with a gradual rise from 2:12.8, average record of the sires of the five year old class, to 2:16.49, average record of sires of the ten year old class. A similar comparison of the records of the dams of the individuals shows a variation of 2.33 seconds.

The column headed "average seconds difference from individuals" shows that the sires are faster than the individuals in every case, but that on account of the sires of the horses that made a record later in life being slower

than those sires of horses that made their record early, the records of the sires and individuals seem to approach each other as age advances. In examining the average difference in the records of dams and individuals it is noted that in most cases the get are faster than the dams and that there is an increase in this difference as the age of individual concerned increases. Table No. I indicates that the average record of the get is between the average records of the sires and dams, and that it more closely resemble that of the dams, as shown by the columns, average seconds difference from sire and dam.

Table No. II is similar to No. I in all instances except in the average seconds difference in speed of the dams from that of the individuals. The difference here is that in No. I the dams are all slower than the individuals, while in table No. II the dams are faster than the individuals in all instances except one - nine year old class. This difference is accounted for by the fact that the dams of all individuals whose records are included in table No. I are trotters while those in table No. II are pacers. These are therefore not comparable unless the records are placed on a basis of the same gait.

The American Trotting-Horse Association, has, after comparing thousands of records of horses, decided that a

a record of 2:30 at the trot is equivalent to 2:25 at the pace, and upon this basis have made the standard of their registry. If in these tables and curves under discussion, the records are reduced to a common gait, by adding or subtracting five seconds to the record used they would be comparable and each would show practically the same tendencies.

Table No. V is similar to table No. I, except that the difference in average speed of sires and individuals is less in the former and the difference in the average speed of the individuals and the dams is greater in the later. This difference is accounted for by the fact that the individuals were pacers and the sires and dams were trotters. If the record of each individual, sire and dam were reduced to a common gait, tables No. I and V would be more nearly similar.

Table No. VI shows practically the same difference as pointed out above, i.e. that the variation from the individual varies according to the gait at which the sire and dam made their record. In Table No. VIII the above is shown with one exception, viz; that the dams have a lower record in most cases than the individuals. In this table only a few individuals are represented in the mature animals- 11 stallions, 44 mares and 22 geldings. This is not a sufficient number from which to make deductions.

Discussion of Plates

The curves following each table show the following:
In Plate No. I, the speed of the sires exceeds that of the dams and individuals and that the speed of the individuals is between that of the sires and dams but more closely follows that of the dams.

In plate No. II the same is seen with the exception that there is less difference between the records of the sires and dams. This is due to the fact that dams are pacers. If the pacing record of the dams was reduced to equivalent trotting record by adding 5 seconds, almost the same condition as is seen in plate I would be had. The sharp angles and extreme variation as seen here is caused by the small number of individuals considered.

In plate No. III the same difficulty as experienced above is met. The small number of individuals considered probably causes the wide variation and the sires' pacing records shows wide variation from the trotting record of the individuals and dams, yet with the mares and geldings a close similarity of the speeds of the individuals and dams is noted. Plate No. IV is omitted on account of not containing a sufficient number of records to be of any value in this discussion.

In plate No. V the speed of sires and dams has

the same relative position, i.e. the dams are slower than the sires, and that the speed of the individuals falls between them but it more closely follows the speed of the sire. In this case the get are pacers. If these pacing records were reduced to equivalent trotting records a curve similar to plate I would result. In plate VI the speed of the individuals, sires and dams, are shown as being practically the same. In this case the individuals and dams are pacers while the sires are trotters. To make these comparable the sires' trotting record must be reduced to the equivalent pacing record, thus lowering the record five seconds. Then the same condition as noted in the foregoing plates is seen, i.e. the dams' record is slower than the sires' and that the individuals' falls between the two closer to that of the dams.

In plate VII practically the same conditions as noted in plate III are seen. Here the individuals and sires are pacers, while the dams are trotting animals. This causes a wide variation between the speed of the dams' and the sires' and individuals but by reducing the dams' trotting records to their equivalent pacing records this plate shows practically the same as those discussed. In plate VIII the dams' records are faster than those of the individuals' and sires'. This, judging from the foregoing plates is not what would be expected. One cause which contributes to this irregularity is that the number of individuals considered is too small-only 11 stallions, 44 mares, 22 geldings..

Table No. IX. A Summary of the Average Records of All Individuals, i.e. Stallions, Mares and Geldings, in tables I-VIII, given by ages.

Age when Record was taken	Table I	Table II	Table III	Table IV	Table V	Table VI	Table VII	Table VIII
2	2:24.90	2:27.88	2:21.75	2:24.64	2:22.41		2:23.53	2:24.49
3	2:24.08	2:24.76	2:25.49	2:29.50	2:19.70	2:23.69	2:15.25	2:18.81
4	2:23.06	2:23.47	2:17.87	2:23.25	2:20.38	2:20.17	2:20.83	2:20.07
5	2:19.36	2:21.50	2:24.18	2:20.25	2:17.71	2:17.94	2:17.35	2:15.32
6	2:18.51	2:19.51	2:19.12	2:23.25	2:15.10	2:16.25	2:18.37	2:17.49
7	2:20.25	2:21.75	2:21.87	2:18.25	2:15.26	2:21.37	2:11.68	2:16.69
8	2:20.90	2:22.59	2:20.06		2:15.66	2:15.95	2:13.71	2:15.15
9	2:20.76	2:16.18	2:25.75		2:16.10	2:17.69	2:13.50	2:15.44
10	2:19.03	2:21.87	2:16.25		2:15.62		2:16.25	
11	2:19.40	2:20.25	2:14.50		2:15.18		2:14.15	2:19.75
12	2:19.09	2:18.00		2:24.50	2:21.25

Plate No. IX. Summary of all classes of animals in plates Numbers I, II and V.

Plate No. X. Summary of all classes of animals in Plates Numbers VI and VIII.

Discussion of Summary of Tables I-VIII.

In Table No. IX, a summary of Tables I - VIII, it is noted that where the gait of the individuals, sires, and dams is the same, the average record of the sires exceed that of the individuals, and that the average record of the individuals exceeds that of the dams. In the other tables where the gaits are not the same, this condition may be had by reducing all records to that of a common gait as explained before.

The variation of the average speed of the sires from that of the individuals is greater than the variation of the speed of the dams from that of the individuals. The summary indicates that the average speed of the get falls between that of the sire and dam, but it is not the mean between the two.

At least a partial explanation of this fact may be seen from the following:

In many cases mares are taken from the track and placed in the stud as soon as they have taken a record better than 2:30 trotting or 2:25 pacing.

Since the public and mare owners show a decided tendency to judge a stallion's ability as a sire by his performance record, there is a general tendency to train stallions to their full development.

Stallions may have 10 to 90 of their get foaled each year, while mares at best only produce one offspring each year. Consequently there is a much greater opportunity for selection among stallions than among mares. This condition tends to bring about the use in the stud of stallions of comparatively great promise, or with fast records. It also points to the fact that mares of much less promise and with less fast records must be used in the stud in order to produce a normal crop of foals. In other words mares with less inherent speed and less desirable pedigrees are used for breeding purposes. Thus mares used for dams are nearer the mean or, average of the race, than is the case with the stallions.

Galton¹ observed in his work with statures of men that there is a tendency on the part of a race to regress toward its mean. It will then be seen that the records of the dams are between the mean of the race and the exceptional individual of the race,- the sires. Since the dams here listed are above the average dams of the race, regression will be seen to have an effect upon the relation of the classes of horses concerned.

It is then evident that the natural regression expected and found in both sires and dams tends to bring the record of the individual closer to the record of the slower or less exceptional parent, the dam.

1. Natural Inheritance - Galton, page 208.

Discussion of Summaries of Plates

Plates No. IX and X are summaries of plates numbers I, II, V, VI and VIII. In these curves the average records of stallions, mares and geldings, their sires and dams were used. This gives a larger number of individuals in the general average than has been used in the other plates, thus these summaries should be comparatively more dependable.

A study of the summaries of the several plates shows approximately the same relation of the average speed of get, sire and dam as is shown in the original plates by each of the classes separately. One difference noted is that the line representing the average speed of each class of animals is not so irregular in its variation. This results from the large number of individuals used in average.

Mean Speed of Dam 2:20.93
Mean Speed of Get 2:19.50

[illegible]

Table No XI, Individual Subject, Sire Relative.

[illegible]

Mean Speed of Sire, 2:14.25

Mean Speed of Individual, 2:19.50

V. CORRELATION BETWEEN THE SPEED OF SIRE AND DAM AND THAT OF THE GET.

In order to show the correlation of the speed of the sires and dams with that of the individuals regression tables were made. In arranging these regression tables the records that contained fractions were given in whole numbers. Those that contained $1/4$ and $1/2$ were counted as the whole number while those that contained $3/4$ were counted as the next whole number above that given. For instance, a 2:25 $1/4$ or 2:25 $1/2$ record was inserted as a 2:25 record and a 2:25 $3/4$ record was used as a 2:26 record. Such methods of procedure are objectionable, yet in a case like the above where each record of sire, dam and individual is treated by the same method of procedure the relation of one to the other should not be altered.

Table No. I, Trotting Individuals sired by Trotting Stallions out of Trotting Mares, contains the majority of individuals whose gait is the same as that of the sires and dams and are comparable, therefore this one is represented by the regression tables. Mature individuals those that made records at five years of age or older - were used in these tables.

Table No. X, is the arrangement of the records of the

352 trotting individuals with the trotting records of their dams, and Table No. XI, is a similar arrangement of the records of the same individuals with those of their sires. The horizontals show the range of the variation in the speed of the parents capable of producing offspring with the same speed, and the verticals show the range of variation in the speed of the offspring of parents having the same speed. In these tables the speed of only one parent is compared with that of the offspring. Where there is a wide variation in the speeds of the parents erroneous conclusions may be drawn unless the factor of the influence exerted by the other parent is taken into consideration.

Discussion of Regression Tables.

Table No. X, shows an uneven distribution of the population, with the largest numbers clustering in the lower right-hand corner. This table represents the upper left-hand one-fourth of a regression table that shows a tendency of the larger numbers to be clustered in the center. In this work only the performing individuals are used, but if the total population of the race could be considered it is probable that a regression table would be formed that would show a tendency to cluster about the center and the one here presented would represent the upper left-hand fourth of it.

In few cases the records of the get and the dam were the same. The greatest number of individuals found with the same record was 29 in the 2:19 and 2:2:21 classes and greatest number of dams found with the same record was 25, in the 2:29 class. The mean speed for the dams is 2:20.93 and for the get 2:19.50. The coefficient of correlation is .06987 or approximately 7 per cent correlation between the speed of the dam and get. Wide variations in speed of dams and get are shown. For instance, the dam of the fastest individual included in the list, 2:03 1/4, has a record of 2:27, and the same class of dams - 2:27 record - have get with a record of 2:29. Those get that made a record of 2:28 are from dams whose records range from 2:09 to 2:30, but the majority of these dams have records slower than 2:25. This wide variation may be due to the factor introduced by the sire which might have been an exceptional animal, or it may be attributed to the fact that the record inserted here do not represent the highest speed that the dams were capable of making. The latter is probably the cause of this wide variation since many mares are placed in the stud before they are fully developed for their inherent speed.

In Table No. XI, the tendency is for the larger figures to be concentrated in the lower center, somewhat nearer the left-hand side of the table. This is caused by the use of the

stallions with low records - exceptional individuals of the race - ---- for sires. . The greatest frequency of get for any one record is 29 in the 2:19 and 2:21 class, as was found in the preceding tables, and that for the records of the sires is 32 in the 2:15 class.

The mean speed of the sires is 2:14.25; and for the individuals 2:19.50. The coefficient of correlation is .03382, or there is 3.38 percent correlation between the speed of the get and that of the sires. Variation as has already been pointed out exists here. For instance, those horses that made records of 2:18 have for sires stallions ranging from 2:02 to 2:29. These variations are only instances in the table but may be seen in practically all class of individuals studied.

By considering these regression tables together it is possible to arrive at some definite conclusions concerning the relative influence exerted upon the offspring by the sire and dam.

The mean speed of the sires, dams and individuals is, 2:14.25, 2:20.93 and 2:19.50 respectively, and the coefficient of correlation for sires and individuals is .03382 and for dams and individuals is .06987. There is a tendency on part of the get to resemble the slower parent, the dams, or to become mediocre performers. In all breeding there is a tendency on the part of the offspring to a regression to the mean of the race. This regression is sometimes called the "drag of the race", and is

simply the influence exerted by the ancestors beyond the immediate parents. From this it is seen that the average offspring of an exceptional parent is less exceptional than this parent and tends towards the average of the race.

The speed of the dams is not the mean speed of the total population of trotting horses but it is nearer the mean speed than that of the sires and therefore there is a tendency for the speed of the get to be more closely associated with that of the dams.

Although the regression tables show a greater correlation of the speeds of the get and dam than of the get and sire, it is not safe to conclude from these data that the speed is more closely associated with the female of the race. The factor of regression or "drag of the race," must be considered as having no small effect.

VI. INFLUENCE OF SEX UPON THE INHERITANCE OF SPEED

In tables I-VIII of this discussion it is noted that in most cases the records of the sires are lower than those of the dams. It is a fact that the average of the records of sires is lower than that of the dams. But it does not necessarily follow that the records of stallions are, on the average, lower than those of the mares.

Comparison of Records of Stallions, Mares and Geldings.

Table No. XII, shows that there is no appreciable difference in the average records of the individuals regardless of whether stallion, mare or gelding. It will be noted in the original tables that the average records of those geldings, that were made under six years of age, are slower than either those of the stallions or mares. This class of animals represented a slow class of stallions that did not show speed, and as horses with low records are to be preferred as sires, these were gelded. These geldings are then trained for a short while and if they do not show speed are discarded. This makes the average record for geldings higher than the other classes before these inferior individuals are discarded.

The fact that our recent "worlds records" are being held

The following table is made from extracts from the preceding tables.

Table No. XII

Age at which record was made	No. of indi- duals used in average.	Gait of individ- ual	Class of Animals	Average record of individual	Extract taken from Table No.
3	47	Trot	Stallion	2:24.11	I
3	62	"	Mare	2:24.05	
3	7	"	Gelding	2:24.21	
<u>6</u>	19	Trot	Stallion	2:18.10	I
6	36	"	Mare	2:18.36	
6	25	"	Gelding	2:19.09	
5	10	Pace	Stallion	2:17.82	V
5	11	"	Mare	2:17.25	
5	5	"	Gelding	2:18.50	
10	9	Trot	Stallion	2:18.36	I
10	7	"	Mare	2:19.68	
10	4	"	Gelding	2:19.44	
7	4	Pace	Stallion	2:16.87	V
7	6	"	Mare	2:15.03	
7	4	"	Gelding	2:14.00	
8	19	Trot	Stallion	2:21.97	I
8	25	"	Mare	2:21.21	
8	11	"	Gelding	2:18.56	

by stallions and geldings does not indicate that the male has more inherent speed than the female. Bearing upon this condition is the fact that the stallions and the exceptional geldings generally receive more training than the mares, as explained in the preceding chapter.

¹
Redfield states, "Among American trotters the mares are known to be greater performers than the stallions." The data presented in this work do not indicate that either stallions, or mares are the greater performers on account of the sex, but that the class receiving the more training are better performers. This conclusion is based on the facts that with the individuals, which have the same opportunity up to the time the record is made, there is no appreciable difference in the records of the stallions and mares, but with the sires and dams the difference is in favor of the sires, which are trained longer and given more opportunity for development.

Comparison of Speed of Sires and Dams with that of the Sons and Daughters.

Table No. XIII is an extract from table No. I, showing a comparison of the speed of mares and stallions with that of their sires and dams. It is noted that the average difference in speed of the stallions from their sires is 6.77 seconds and for the mares is 5.70 seconds or slightly more than one seconds

Table No. XIII, showing relation of speed of sire and dam with that of sons and daughters.

Offspring			Parents		
Age	Number	Av. Record	Av. Record	Av. Record	Av. Record
Considered		of Stallion	of Mares	of Sires	of Dams.
5	32	2:17.14		2:11.20	2:20.60
6	19	2:18.10		2:11.44	2:19.08
7	23	2:18.13		2:13.57	2:22.75
8	19	2:21.97		2:11.96	2:23.92
9	8	2:22.15		2:14.44	2:24.72
10	9	2:18.36		2:17.03	2:25.08
11	3	2:18.58		2:10.66	2:14.69
Total:	113				
Average Records:		2:18.80		2:12.53	2:21.83
5	64		2:19.84	2:23.70	2:21.13
6	36		2:18.36	2:12.68	2:20.00
7	33		2:21.72	2:15.13	2:17.82
8	25		2:21.21	2:15.82	2:23.12
9	13		2:20.83	2:16.48	2:20.73
10	7		2:19.68	2:17.32	2:19.96
11	5		2:19.70	2:12.35	2:19.85
Total:	183				
Average Records:			2:20.13	2:14.33	2:20.47

difference.

The average record of the stallions differs from that of the dams by 3.03 while the average record of the mares varies from that of the dams by only .34 second. This difference is not due to the fact that stallions are faster than mares, but is probably due to the fact that stallions are trained longer than mares, as has been explained before.

From the data here presented there is no evidence that speed is transmitted differently from sires and dams to sons and daughters.

SUMMARY

Standard Trotting horses mature at between five and six years of age.

The average record of the sires of Standard Horses is faster than the average record made by the dams.

The average record made by Standard Trotting horses falls between the average record made by their sires and the average record made by their dams.

The average record made by the Standard Trotting horses differs less from that made by the dams than that made by the sires.

For the Standard Trotting horses here considered the correlation between the records of the dams and the offspring is approximately twice as great as the correlation between the speed of the sires and offspring.

Among Standard Trotters there is no evidence that the male or female offspring resemble either the parent of the same or the opposite sex more closely than the other parent, with respect to speed.

The average record of Standard Trotters corresponds more closely to the average record of the dams than the average record of the sires but when factors other than inheritance, but necessarily operative, are taken into consideration it is not safe to conclude from the data here presented that either immediate parent of Standard Trotters exerts a greater influence upon the offspring than does the other parent.

May 16, 1915.

Dr. George Lefevre,
110 Biology Bldg.

My dear Dr. Lefevre:

It is customary for the Graduate Committee to refer dissertations, submitted by candidates for the degree of Master of Arts, to some member of the Group who is not connected with the Department in which the candidate's work has been done. I am sending you herewith a dissertation which has been submitted by O. L. Farris.

I shall be greatly obliged if you will kindly examine the same at your earliest convenience and report to us for the Graduate Committee whether in your opinion the dissertation meets the general standard which has been established in this University for the Master's dissertation.

Very truly yours,

A handwritten signature in cursive script, appearing to read "Walter Miller".

Chairman, Graduate Committee.

Approved
Georg Reiser

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