

ON THE RELATION OF RACE CROSSING TO THE SEX RATIO.

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INTRODUCTION.

There would appear to be widely prevalent among practical stock breeders an opinion that the relative proportion of the sexes may be influenced by the method of breeding practiced. As evidence of the existence of such an opinion two citations will suffice. Others might be given. Davenport in his memoir on "Inheritance in Poultry,"¹ introduces a section on "Sex in Hybrids" (p. 97) with the statement that: "There is a widely held and frequently expressed opinion that hybrids show an excessive proportion of males." He further says that: "Bateson and Saunders probably have this in mind in their statement — 'the statistical distribution of sex among first crosses shows great departure from the normal proportions.' " No support is given to the view that hybrids show an undue proportion of males by Davenport's own statistics, the general conclusion being that: "The exceptions to the law of equality of sexes in hybrid offspring are . . . individual and not of general significance."

It is a matter of interest to note that while the opinion appears to be widespread that the kind of breeding practiced influences the sex ratio there is not entire uniformity as to what the influence of a particular method of breeding on sex is. Thus one would infer from a statement in a recent work by Müller² that it has been generally held by continental breeders, at least, that *inbreeding* tends toward the production of an unduly large proportion of males. Müller² (*loc. cit.*) in discussing the experiments of Schultze (*cf. infra*) makes the following statement concerning certain of that author's results: "Das Verhältniss der beiden Geschlechter war vielmehr bei strengster Inzucht (Paarung nur

¹ Carnegie Institution of Washington, Publication No. 52, 1906.

² Müller, R. "Biologie und Tierzucht." Gedanken und Tatsachen zur biologischen Weiterentwicklung der landwirtschaftlichen Tierzucht. Stuttgart (Ferd. Enke), 1905. Pp. 96.

mit Bruder, Enkel, Urenkel, Vater und Grossvater) ein sehr verschiedenes, ja in einigen Fällen kamen sogar in der dritten Geschlechtsfolge, *ganz in Gegensatze zu der alteren Annahme*,¹ überwiegend weibliche Nachkommen zur Welt."

Investigations systematically directed towards determining in what way and to what extent either hybridizing or inbreeding affect the sex ratio are very few in number. Davenport (*loc. cit.*), from a tabulation of the sex of 377 fowls reaches the conclusion already stated regarding the influence of hybridization. Schultze² has studied in mice the effect of inbreeding of various degrees including the closest "Inzestzucht" on sex determination, and reaches the conclusion that in general it has no effect.

The search for factors which may determine or influence sex is being actively prosecuted by experimental biologists. Any data tending to throw light on the significance of any supposed sex-influencing factors can but be welcome. The quotations from the literature which have been given suffice to indicate that the character of a mating must at least be accorded the place of a "supposed" sex-influencing factor. It is the purpose of the present paper to exhibit and discuss certain data which have a direct and definite bearing on the question of the significance of this factor in the case of one organism, namely, man.

The data which form the basis of this paper are extracted from the published vital statistics of the city of Buénos Ayres. For nearly twenty years past this city has maintained an elaborate system of municipal statistics. Indeed its system might in many respects well serve as a model. It is doubtful whether the statistics of any other city or country surpass those of Buénos Ayres in completeness and accuracy. These records are published in annual volumes, of which fifteen have appeared. The statistics of births given in these volumes are particularly detailed. Among other matters of general biological interest there is given each year a table setting forth the number of births occurring in the year covered by the volume, classified in such way that it appears for each child born whether it was (*a*) male or female, (*b*) legiti-

¹ My italics. — R. P.

² Schultze, O. "Zur Frage der geschlechtsbildenden Ursachen." *Arch. mikr. Anat.*, Bd. 63, Heft. I, 1903.

mate or illegitimate, and (c) what was the nationality of each of its parents. Furthermore it should be said of these statistics that they are *registration* figures and not *census* returns. That is to say, they are definite *records* of events, each event being recorded when it happens, not more or less inaccurate counts made a long time after the event. Of the substantial accuracy of these figures there can be no doubt.

As is well known, Buénos Ayres is a city having a population which is racially very heterogeneous. For a decade and more past there has been a large Italian immigration. Also there has been extensive Spanish immigration. Representatives from other nations have come in in smaller numbers. From the statistics of birth above alluded to it is possible to determine what has been the sex of the offspring of each of these racial groups in pure matings and when crossed with native Argentine stocks. For the purpose of the present study the birth statistics of the ten years 1896-1905 inclusive have been used. The following matings have been considered :

Argentine	♂	Argentine	♀
Italian	♂	Italian	♀
Spanish	♂	Spanish	♀
Italian	♂	Argentine	♀
Spanish	♂	Argentine	♀

Data are available for other matings but it has not seemed advisable to deal with any yielding less than 8,000 offspring in the ten years. The inquiry has been further limited to legitimate births, because of the uncertainty which must always exist in the great majority of illegitimate births as to whether the putative father is the actual one. With these restrictions the number of separate offspring dealt with in this study approaches a quarter of a million (exactly 219,516).

These statistics have been studied with the purpose of obtaining answers to the following questions :

1. Is there a tendency towards an excessive production of offspring of one sex (either male or female) in cross as compared with pure matings, among the human racial stocks under consideration ?

2. If such a tendency appears to exist is it (a) uniformly shown in all the matings considered, and (b) numerically great enough in amount to be considered significant when tested by probable errors?

DATA.

The raw material on which this paper is based is set forth in Table I. The figures are extracted from Volumes VI. to XV. inclusive of the *Annuaire statistique de la ville de Buénos-Ayres*.¹

TABLE I.

SEX DISTRIBUTION OF LEGITIMATE BIRTHS. RAW DATA.

National- ality of Parents.	Argentine ♂ Argentine ♀		Italian ♂ Italian ♀		Spanish ♂ Spanish ♀		Italian ♂ Argentine ♀		Spanish ♂ Argentine ♀	
	♂ ♂ Born.	♀ ♀ Born.	♂ ♂ Born.	♀ ♀ Born.	♂ ♂ Born.	♀ ♀ Born.	♂ ♂ Born.	♀ ♀ Born.	♂ ♂ Born.	♀ ♀ Born.
1896	1,597	1,654	5,326	5,455	1,814	1,695	939	932	349	411
1897	1,722	1,712	5,740	5,499	1,767	1,728	1,060	968	431	394
1898	1,922	1,773	5,765	5,703	1,805	1,695	1,152	984	431	420
1899	1,980	1,945	5,770	5,743	1,887	1,790	1,168	1,100	478	417
1900	2,038	1,950	5,070	5,620	1,809	1,784	1,126	1,064	458	411
1901	2,163	2,099	5,923	5,771	1,879	1,806	1,178	1,192	461	421
1902	2,189	2,100	5,736	5,597	1,837	1,781	1,204	1,189	463	438
1903	2,277	2,200	5,341	5,133	1,780	1,702	1,214	1,127	467	448
1904	2,352	2,368	5,419	5,240	1,952	1,723	1,345	1,215	521	460
1905	2,533	2,317	5,507	5,409	2,093	1,940	1,294	1,277	516	468
Totals	20,773	20,118	55,597	55,170	18,623	17,644	11,680	11,048	4,575	4,288

It is at once apparent that these statistics show essentially the same relation of the sexes as that usually found when large numbers of human births are examined, namely, a preponderance of males. The extent of this preponderance may be shown best by putting the data in the form of sex-ratios. In this paper the sex ratio will be taken as the number of males to each 100 females. The sex ratios deduced from the totals of Table I. and their probable errors are given in Table II. It does not appear to be necessary or advisable to deal with the single years separately. The method of determining the probable errors of the sex-ratios was to determine first for each mating the probable error of the absolute frequency of males, considering this as a simple class

¹ Published by the Direction générale de la statistique municipale, Buénos Ayres.

frequency. It has been shown¹ that if y_s be any class frequency within a sample containing m individuals altogether, then

$$P \cdot E \cdot y_s = .67449 \sqrt{y_s \left(1 - \frac{y_s}{m} \right)}.$$

From the "absolute" probable error so obtained the probable error of the sex-ratio is easily deduced.

TABLE II.

MALES TO 100 FEMALES FROM TOTALS OF TABLE I.

Mating.		Sex Ratio.	Mating.		Sex Ratio.
Argentine ♂	Argentine ♀	103.26 ± .34	Italian ♂	Argentine ♀	105.72 ± .46
Italian ♂	Italian ♀	100.77 ± .20	Spanish ♂	Argentine ♀	106.69 ± .74
Spanish ♂	Spanish ♀	105.55 ± .36			

From this table the following points are to be noted :

1. The number of males to 100 females varies between approximately 101 and 107 in the different matings. There is an excess of males in every case. Further, this excess is significant in amount as is indicated by the probable errors. The present statistics agree with other large collections of data regarding the sex-ratio of human births. There appears to be no doubt that a tendency towards the production of a greater number of males than of females is normal for Caucasian races at least.

2. The sex-ratio is in each case higher for the cross matings than for the pure. That is, there are more males per hundred females produced when the parents are of different racial stocks than when they are of the same.

The answer to the first question propounded above (p. 196) then is that there is a definite tendency towards an excessive production of male offspring in cross as compared with pure matings in the data here considered. Further, it appears that within the limits of the present material this tendency is uniformly exhibited in all the matings.

Attention may next be turned to the second part of the second question, which may now be put as follows :

¹ Editorial — "The Probable Errors of Frequency Constants," *Biometrika*, Vol. II., p. 274.

Is the excess of male births in cross matings numerically great enough to be considered significant in comparison with the probable errors involved? The evidence on this point is presented in Table III., which compares the sex-ratio for each cross mating with that for each of the two pure matings related to it. The last column of the table gives the ratio of the difference in each case to the probable error of the difference. In interpreting this last column it will be remembered that a difference which is three or more times as large as its probable error is to be regarded as significant; a difference which is between two and three times its probable error is probably significant; while a difference less than twice its probable error when taken by itself is probably not significant. In general, the technical biometrical use of the term "significant" intends to convey the idea that the odds are so great as to amount to practical certainty that a so-called "significant" result did not arise simply as a purely chance effect of random sampling, but represents a direct causal nexus between phenomena.

TABLE III.

COMPARISON OF THE SEX-RATIOS OF THE OFFSPRING OF PURE AND CROSS MATINGS.

Matings.		Sex Ratio.	Difference P. E. of Difference
Italian ♂	Argentine ♀	105.72 ± .46	
Italian ♂	Italian ♀	100.77 ± .20	
Difference		4.95 ± .50	9.9
Italian ♂	Argentine ♀	105.72 ± .46	
Argentine ♂	Argentine ♀	103.26 ± .34	
Difference		2.46 ± .57	4.3
Spanish ♂	Argentine ♀	106.69 ± .74	
Spanish ♂	Spanish ♀	105.55 ± .36	
Difference		1.14 ± .82	1.4
Spanish ♂	Argentine ♀	106.69 ± .74	
Argentine ♂	Argentine ♀	103.26 ± .34	
Difference		3.43 ± .81	4.2

From this table it appears that the excess of male births in the cross matings as compared with the pure is in general large in proportion to its probable error. In only one out of the four

possible comparison cases is the difference less than four times its probable error. In that case (Spanish-Argentine and Spanish-Spanish) the difference is 1.4 times its probable error, and could not, taken by itself, be considered significant. Taking into account, however, the facts that (a) the difference is of the same sense as the other differences in the table and (b) that it is larger than its probable error the general conclusion reached from the other figures is not vitiated. This conclusion is that within the limits of the present material *there is evidence of the significantly greater proportionate production of males in the offspring from matings involving different racial stocks than in the offspring from matings in which both parents belong to the same racial stock.*

DISCUSSION.

The data which are set forth in the tables given above appear to lead clearly to the conclusion which has been drawn from them. This conclusion, however, is merely a statement of fact. In interpreting it it remains to consider two points. The first of these is as to whether there are limitations or fallacies in the data themselves which invalidate the conclusion to which they appear to lead. The second is as to what is the meaning of the facts implied by this conclusion supposing it to be true. One cannot be too cautious in drawing conclusions from human vital statistics of whatever kind. Vital statistics notoriously abound in pitfalls. In a critical examination of the data with a view to possible criticism and interpretation the following points suggest themselves :

1. That the material is not sufficiently extensive. It might conceivably be maintained that if a larger number of births were to be dealt with they would show a different result. For two reasons such a consideration appears to have little weight. In the first place the number of births included in the statistics is extremely large as measured by biological standards. The statistics include upwards of 200,000 births. In the second place the probable errors of the sex-ratios indicate how literally enormous are the combined odds against such a consistent system of differences as that shown in Table III., arising fortuitously. In this connection it may be said that the work was begun in the

first instance with the statistics for three years (1903, 1904 and 1905) only. The figures for these years led to exactly the results which have been shown above. The figures for the seven previous years were then taken into the calculation to see whether they would confirm or reverse these results. That they confirm them is clear.

2. That the inclusion of living births only in the statistics influences the result. That statistics of sex should theoretically include still-born as well as those born living is obvious. The still-born would have been included in the tables of this paper had it not been for the fact that the original material was tabulated in such way as to render it impossible to include them. A little consideration shows, however, that the absence of still-born does not sensibly affect the conclusion drawn from the present statistics. It is a well-known fact that among still-born children the proportion of males to females is very much greater than among living born. It does not seem necessary to cite evidence of this fact; all large collections of birth statistics show it. Pains have been taken to make sure that the records of still-born in Buénos Ayres form no exception to the general rule.

Now there are three possibilities respecting the distribution of still-born young among the offspring of the cross and pure matings discussed in this paper. These are:

(a) That still-births are distributed *pro rata* among cross and pure matings. This is the most probable supposition. It would be expected on general grounds that in the long run there would be substantially the same number of still-births among a given total number of births whether this total originated from cross or pure matings.

(b) That a relatively larger number of still-births originate from pure than from cross matings.

(c) That a relatively large number of still-births originate from cross matings than from pure.

It being a fact that still-births show a high sex-ratio it is evident that a distribution of such births in accordance with (b) could alone tend to reverse the conclusion reached from statistics which leave these births out of account. In case they were distributed as in (a) or (c) their inclusion would simply make

more pronounced the results found in their absence. It appears highly probable on general grounds that if still-births are not proportionately distributed among cross and pure matings there is somewhat more likely to be an excess of such births arising from cross (*i. e.*, according to (*c*)) than from pure matings (*i. e.*, according to (*b*)). It is hardly conceivable that there could be a steady tendency for a sensibly greater number of still-births to occur when both parents are of the same nationality than when they are of different nationalities. If this be granted then it must also be granted that the non-inclusion of still-births in the present statistics cannot be adduced as an explanation of the observed preponderance of males in the offspring of cross matings.

3. That a different age distribution of the parents in cross as compared with pure matings may account for the observed preponderance of male births from such matings. In a population such as that here dealt with it is undoubtedly true that the males in the cross matings (being for the most part probably immigrants) are on the average somewhat older than those in the pure matings. It might conceivably be contended that this greater average age of the male parent was the cause of the excessive production of male offspring in the cross matings. To make such a contention, however, would simply be to affirm belief in Sadler's "law"¹ or some variant of it which holds that the relative age of the parents is causally related to the sex-ratio of the offspring. In regard to this matter it need only be said that Sadler's theory has been abandoned by all recent students (both from the biological and from the demographic side) of the problem of sex simply for the reason that nothing remotely approaching conclusive evidence has ever been brought forward in its support.

4. That the individuals in the cross mating are exposed to environmental influences different on the average from those acting on the individuals in pure matings and that the differences in the sex-ratios of the offspring of these two groups are the result of these environmental differences. This possible explanation obviously needs careful consideration. So far as broad environ-

¹ Cf. Geddes and Thomson, "The Evolution of Sex" or any of the standard works on vital statistics for an account of this law.

mental factors such as climate are concerned there can be no differential effect on the sex-ratio for the two groups since all the statistics are derived from the population of a single city. In a general sense all the individuals live in the same environment. But there is a possibility of a difference between the different groups in regard to the complex of environmental factors which are collectively implied in "social status." It is conceivable that on the average the Italian-Argentine families are of different social status than Italian-Italian or Argentine-Argentine families in the same city. Differences in social status imply differences in nutrition, in housing and in other physical conditions of existence. Some one or all of these things might conceivably be held to affect the sex-ratio in the manner observed. In considering this point it needs to be held clearly in mind that there are two distinct questions involved. These are: (a) Is there any conclusive evidence that there does exist as a matter of fact any uniform average difference in the social status of individuals in cross as compared with pure matings? And (b) granting that such an average difference does exist what evidence is there that it would produce the observed effect on the sex-ratio? To the first of these questions it is difficult to get any answer. Careful study of all the available demographic statistics of Buénos Ayres has failed to yield any conclusive evidence on the point. The probability appears to be, however, that if any difference at all exists in the social status of the two groups it is in the long run (or on the average) not marked in degree. Further it appears probable that whatever difference does exist is in the direction of a lower social status in the case of the cross matings.

Regarding the influence of such a difference (if it exists) on the sex-ratio it seems probable that it would have very little or no effect. Punnett¹ has recently made a very careful study of just this point for certain elements of the population of London. He finds that in the classes of lower social status more females than males are born, and *vice versa*, but concludes in general that parental nutrition has no sensible influence on the sex-ratio. Morgan² reviews the literature on the subject and reaches the fol-

¹ Punnett, R. C., "On Nutrition and Sex Determination in Man," *Proc. Camb. Phil. Soc.*, Vol. 12, 1903.

² Morgan, T. H., "Experimental Zoölogy," New York, 1907, pp. xii + 454.

lowing conclusion (p. 385): "If nutrition were really a factor of any importance in sex determination, it is surprising to find so little difference under apparently very favorable and unfavorable conditions. It seems much more probable that if the nutrition affects in any way the proportion of the sexes, it does so indirectly by elimination, and not by determining either the sex of the embryo or of the egg." Further on Morgan says in discussing Geddes and Thomson's theory of sex (p. 388): "If, on the other hand, the determination of sex is supposed to be due to the nourishment of the embryo, the best ascertained facts, both experimental and statistical, are opposed to the hypothesis." Taking all these points into consideration it seems very doubtful, to say the least, if the observed excess of males in the cross matings has its explanation either in whole or in part in differences in the environmental complex implied by "social status." However, in the absence of more complete and definite statistical data regarding the point one cannot be dogmatic in asserting such a conclusion.

If none of the suggested factors can reasonably be held to afford an explanation of the facts regarding the sex-ratio shown by the present statistics how are these facts to be interpreted? All that can safely be asserted is that the present statistics, within their limits, show clearly that there is a definite relation between the character of the mating and the magnitude of the sex-ratio. Is this a *post hoc* or a *propter hoc* relation? The data themselves do not *conclusively* demonstrate which it is. Nor does it seem probable that statistics of human births alone can ever settle this question. It is one which demands experimental analysis. The chief difficulty involved in maintaining that there is a causal relation between the character of the mating and the sex-ratio lies in the lack of knowledge as to what could be the physiological mechanism by which the causation was effected. In a way the phenomenon appears somewhat analogous to the well-known phenomenon of xenia observed in plant breeding, differing in that here the character influenced is sex rather than some purely morphological feature of the organism.

In conclusion it should be said that the data presented in this paper are not put forth as in any way final or conclusive. They

require confirmation from other sources and *experimental* analysis. Within their limits, they lead to a definite and significant conclusion as to fact. In so far they contribute to the discussion of the general problem of determination of sex.

SUMMARY.

Statistics of over 200,000 human births extending over a period of 10 years in the city of Buénos Ayres show that the proportion of males to females is significantly greater when the parents are of different racial stocks than when they are of the same. In the data are involved three racial stocks in pure and cross matings. The preponderance of males in the offspring of cross matings appears not to be capable of explanation as the result of environmental or demographic influences. Experimental investigations are necessary in order to reach adequate explanations of such statistical facts regarding sex ratios as are set forth in this paper.

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