STATISTICAL STUDY OF THE SEX RATIO AT BIRTH

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(With 1 Diagram)

THAT the number of male births always exceeds that of females is well known to students of vital statistics, but the biological law responsible for the phenomenon has not yet been adequately determined though various theories have been offered in explanation. It has been suggested that it resulted from a high male conception rate which, although modified by an excess mortality of male embryos, nevertheless produced a masculinity of matured births. In more recent times the conclusions drawn by MacDowell & Lord (1925, 1925*a*) from their experimental studies with mice have failed to support this view. They claimed that there was no correlation between the pre-natal mortality and the masculinity of live births, that the primary ratio at conception was almost identical with that at birth. These contentions were criticized by Parkes (1923, 1926), who, whilst maintaining the doctrine that the ante-natal mortality of mice "falls preponderatingly upon the males", stated "that it is quite obvious that a great deal more information is required before any coherent story of the factors governing the sex ratio at birth in the mouse (and all other mammals) can be put together".

Heron (1906–7) examined the problem from the standpoint of inheritance. For this purpose he utilized the genealogical data of the Witney family of Connecticut and its affiliations (1649–1878) and also the records from the General Stud Book. In the latter instance 1000 thoroughbred mares were taken at random and the sex ratios of their produce and also that of their dams were calculated. From a very careful and interesting analysis he concluded that "there is no inheritance or at least no sensible inheritance of sex and that such differences as occur must, in some manner, be associated with environment, nutrition or habit".

Although the biological processes which ultimately determine the preponderance of males as compared with females at birth are, as yet, imperfectly understood, nevertheless it is possible to study this problem of masculinity in relation to such purely external factors as age, nationality and social status of the parents; its relation to primogeniture and size of family; its seasonal and secular trend; and the extent to which it is influenced by cross-breeding, migration and social upheavals. Such is the purpose of the present study.

An investigation of a somewhat similar character was made by C. N. & J. N. Lewis (1906). They utilized the records in the Scottish Birth Registers for the year 1853. Their data were unique in the sense that the nature of the

information entered in the birth registers for the particular year was never again recorded. Although the material was fairly extensive, nevertheless, the period of one year is too short for statistical purposes.

Data

The statistics on which the present investigation is based were obtained from (1) the *Annual Reports of the Registrar-General for England and Wales*, (2) the *Reports on Births and Still Births in the United States*, (3) *Annuaire International de Statistique*, and (4) the records of families given in *Burke's Peerage* for the seventeenth, eighteenth and nineteenth centuries.

Sex ratio in England and Wales

We can synopsize the history of the sex ratio at birth in this country—the proportion of males per 1000 females—during the past 95 years in a frequency distribution of the annual indices during that period (Table I). The

Table I. *Showing the distribution of the sex ratios of live births in England and Wales*, 1838–1933

Sex ratio	Frequency	Sex ratio	Frequency
1032–1034	4	1048–1050	6
1034–1036	6	1050–1052	7
1036–1038	11	1052–1054	3
1038–1040	14	1054–1056	2
1040–1042	14	1056–1058	—
1042–1044	12	1058–1060	—
1044–1046	8	1060+	1
1046–1048	8		96

index ranged from 1032 to 1060, the latter value occurring immediately after the war. The mean ratio over the whole period was 1043, and the average dispersion or scatter, as represented by the standard deviation, around this value was 5·7. As the distribution appeared to be of a Gaussian character a normal curve was fitted to the data and the Goodness of Fit test applied. The value of P was 0·650, and from this we conclude that, if the real distribution were Gaussian, we should get by random sampling in 65 out of 100 trials a fit as bad or worse than that obtained. In other words a normal curve gives a good description of the frequency distribution of the sex ratios at birth during a period of nearly 100 years in England and Wales.

London

For London we can study the experience over a longer series of years. The late Dr Newbold, who was interested in this problem of the sex ratio at birth, collected the statistics for a period of 292 years (1629–1920). Her pre-registration data were obtained from the Bills of Mortality and related to christenings and not to births. This, however, does not detract from the importance of the series because, as far as is known, there is no evidence of any selection in the christenings of boys as compared with girls or of any postponement of the christenings of boys until a later date than that of girls.

As an index of the sex ratio she used the proportion of male births to total births and the proportion of male christenings to the total christenings. She found when a frequency distribution of these 292 values was made (Table II) that the descriptive constants were:

$$\beta_1 = 0{\cdot}966 \pm 0{\cdot}366, \quad \beta_2 = 4{\cdot}670 \pm 1{\cdot}225.$$

Table II. *Showing the distribution of the values of P (proportion of male births) for the 292 years, 1629–1920 inclusive, in London*

Values of P	Frequency	Values of P	Frequency
0·494	2	0·518	25
0·498	3	0·522	7
0·502	21	0·526	12
0·506	81	0·530	3
0·510	95	0·534	2
0·514	41		292

Mean = 0·5127, $\sigma = 0{\cdot}006352$, $\beta_1 = 0{\cdot}966 \pm 0{\cdot}366$, $\beta_2 = 4{\cdot}670 \pm 1{\cdot}225$.

Having regard to the large probable errors, it may be doubted whether a departure from the normal system ($\beta_1 = 0$, $\beta_2 = 3{\cdot}0$) has been established.

SECULAR TREND

(a) *England and Wales*

The trend of the sex ratio between 1841 and 1930 in quinquennial periods is shown in Table III. From the beginning of registration until 1900 the

Table III. *Showing the sex ratio in England and Wales in periods of 5 years from 1841 to 1930*

Period	M/F	Period	M/F
1841–45	1052	1886–90	1036
1846–50	1045	1891–95	1036
1851–55	1046	1896–1900	1035
1856–60	1046	1901–05	1037
1861–65	1043	1906–10	1039
1866–70	1041	1911–15	1038
1871–75	1039	1916–20	1051
1876–80	1038	1921–25	1047
1881–85	1038	1926–30	1043

indices declined, the value during 1841–5 being 1052 and in 1896–1900, 1035. There was a slight increase during the ensuing period and, afterwards, the position remained fairly stable until the war and post-war years when the ratio during 1916–20 was no less than 1051. From this high-water mark the index decreased but not to the immediate pre-war level. It is now more comparable with the mean value between 1840 and 1870 than with that between 1870 and 1910.

(b) *London*

When the annual values for the period of 292 years were plotted the general trend was downwards. Dr Newbold realized, however, that these indices were subject to errors of random sampling in consequence of the

smallness of the population on which they were based, particularly the christenings in the initial years. The christenings in 1629 totalled 9901, the number of births in 1920 was 115,659. The question she then had to answer was, to what extent was the downward trend of the annual sex ratios a purely chance movement? The following test was made. The period was divided into two parts, 1629–1849 and 1850–1920. The mean sex ratio of the latter part, where the numbers were considerably larger and the sex proportions more steady, was taken as a standard, and it was ascertained whether the deviations, particularly of the earlier indices, from this mean value could have arisen as simple sampling deviations. The standard value—the mean probability of a male child during the period 1850–1920—was 0·50934. The deviation of each individual sex ratio from this mean was divided by its respective simple sampling deviation—the latter having been obtained by the formula $\sqrt{(pq/n)}$, where n represents the total births or christenings in the year in question. If the deviations from the standard mean of 0·50934, particularly in the period 1629–1849, were only due to the small number of births or christenings on which the ratio itself was based, then these actual deviations expressed in terms of the corresponding sampling or theoretical deviations should not differ much in distribution from a normal curve. The observed frequencies and those derived from the normal curve are given in Table IV

Table IV. *Showing the distribution of the deviations of the annual sex ratios from a P of* 0·50934 (*the mean probability of a male birth in the period* 1850–1920) *in terms of their standard errors for the two periods* 1629–1849 *and* 1850–1920

Deviation / S.E.	1629–1849 Obs.		1629–1849 Cal.		1850–1920 Obs.	1850–1920 Cal.
−5·5 to −4·5	1		0·17		—	—
−4·5 to −3·5	1	6	0·89	4·88	—	—
−3·5 to −2·5	4		3·82		2	2·19
−2·5 to −1·5	10		11·80		7	7·20
−1·5 to −0·5	14		26·40		20	16·06
−0·5 to +0·5	46		42·75		20	20·82
+0·5 to +1·5	76		50·11		11	15·74
+1·5 to +2·5	35		42·52		7	6·93
+2·5 to +3·5	15		26·13		4	2·07
+3·5 to +4·5	10		11·62		—	—
+4·5 to +5·5	6	19	3·74	16·40	—	—
+5·5 to +6·5	3		1·04		—	—
	221		221		71	71
	$\chi^2 = 26·6$				$\chi^2 = 4·27$	
	$N' = 6$				$N' = 5$	
	$P = 0·000070$				$P = 0·374$	

for the two periods 1629–1849 and 1850–1920. When the Goodness of Fit test was applied it was seen that the assumption of a Gaussian distribution was not tenable for the early period as the value of P is 0·000070, but, for the later data, it is a fairly adequate description, P being 0·37. Hence the downward trend of the sex ratio during the period 1629–1849 is a real and not a chance event. This conclusion, as will be seen later, receives additional support from the data obtained from *Burke's Peerage* for the period 1600–1850.

To present a general impression of the secular trend of the sex ratio during the 292 years in question the proportion of male births during successive periods of 20 years was calculated. The observed values together with the calculated regression line obtained from (1) a linear equation, (2) a cubic equation are shown in Diagram I. It will be seen that for all practical purposes the trend represented by a linear equation, a straight line, is an adequate description of the facts.

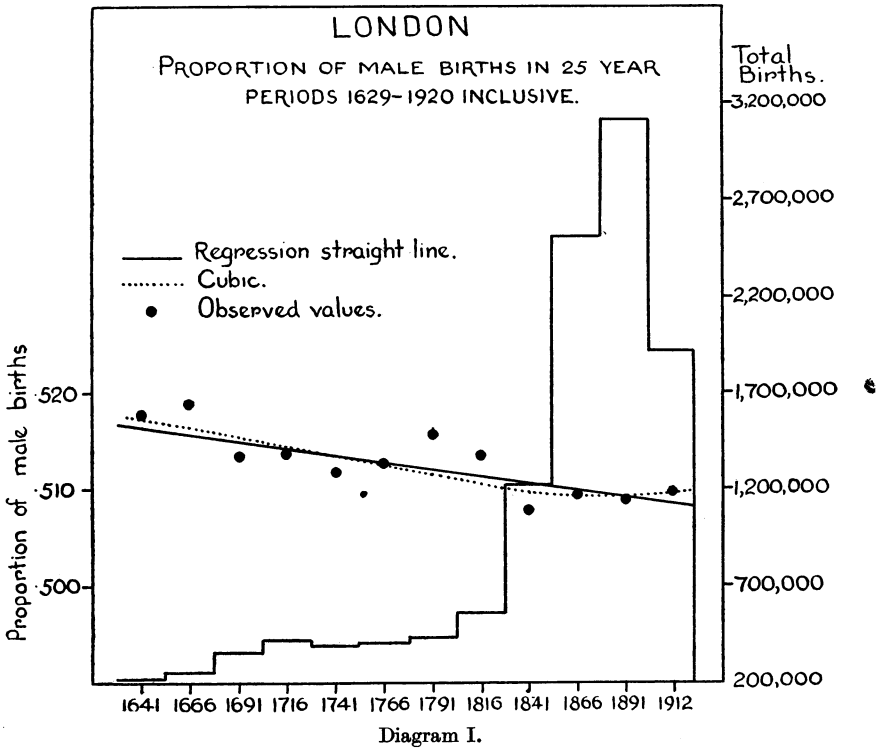

Diagram I.

GEOGRAPHICAL DISTRIBUTION

The ratios have been calculated for the different divisions of the country—North, Midland, South, London, and Wales—for the two decennia 1911–20 and 1921–30. The results with their appropriate standard errors are given in Table V. The standard errors of the sex ratios were calculated from the formula

$$\pm(1+Z)\sqrt{\frac{Z}{N}},$$

Table V. *Showing the sex ratio of live births (M/F) in the different areas of England and Wales*

	Period 1911–20	Period 1921–30
North	1044·4 ±1·23	1044·2 ±1·35
Midlands	1043·2 ±1·23	1047·6 ±1·42
South	1044·3 ±1·44	1044·8 ±1·58
Wales	1044·3 ±2·63	1045·2 ±2·92
London	1044·5 ±2·09	1043·3 ±2·36

where Z = the sex ratio (male per female), and N = the total births. Multiplying the value obtained from the formula by 1000 will give the standard error on the required dimensional scale. It will be noted that the ratios are almost equal in the different areas in 1911–20. During 1921–30 the greatest divergence was between the ratio for London and that for the Midlands, 1047·6 as compared with 1043·3, but the difference, when measured in terms of its standard error, is statistically unimportant.

Urbanization

The association between the degree of urbanization and the size of the sex ratio has been commented on by some writers on the subject. Vigor & Yule (1906) examined the amount and nature of the variation in the sex ratio of births in the different registration districts of England and Wales for the decennium 1881–90. They correlated the proportion of male births per 1000 total births with the total births in each registration district and obtained a correlation of $-0{\cdot}014 \pm 0{\cdot}027$. The present writer using the data of later decennia, 1901–10 for the registration and 1911–20 for the administrative counties, and not for the registration districts, obtained coefficients of approximately this size. The magnitude of the coefficients appears to indicate no relationship but, as Vigor & Yule pointed out, "in reality it misrepresents the position because the mean sex ratio first increases and then decreases in passing from the smallest to the largest urban district". They concluded from their results that "the districts which had the largest proportion of male births were, for the most part, the provincial towns or semi-urban districts, the more purely rural districts and purely urban districts of large towns exhibiting a distinctly smaller proportion". This characteristic is unmistakably present in the data for registration counties for the later decennia. But, it may be asked, are registration districts, and to a greater extent registration counties, suitable areas for the purposes of an enquiry of this nature? It is extremely doubtful, as they are of too heterogeneous a character. Some registration districts may be purely rural in aspect, but, apart from the registration districts which represented the County of London, it is difficult to cite any which were of purely urbanized character. However, if the view expressed by Vigor & Yule is correct it should readily be confirmed by the experience in the present administrative areas into which the country is divided: (1) London, (2) County Boroughs and Boroughs, (3) Urban Districts, (4) Rural Districts, as the size and density of population is strongly demarcated within these zones. The calculated values are given in Table VI. If the statement

Table VI. *Showing the sex ratio at birth according to degree of urbanization*

	Period 1911–20	Period 1921–30
(1) London	$1044{\cdot}5 \pm 2{\cdot}09$	$1043{\cdot}3 \pm 2{\cdot}36$
(2) County Boroughs	$1042{\cdot}4 \pm 1{\cdot}26$	$1044{\cdot}4 \pm 1{\cdot}35$
(3) Urban Districts	$1043{\cdot}3 \pm 1{\cdot}26$	$1045{\cdot}2 \pm 1{\cdot}39$
(4) Rural Districts	$1047{\cdot}8 \pm 1{\cdot}65$	$1048{\cdot}3 \pm 1{\cdot}79$

advanced is correct then the sex ratio of the live births in any of the categories 1, 2 and 4 should be smaller than that in group 3. It will be seen that the results do not support the hypothesis. The index for the county boroughs is less than for the urban districts, but not statistically so, whereas the rural index is the highest of the series. When the difference between the urban and rural ratios was tested for significance it was found that it was definitely outside the limits of random sampling for the first decennium and within for the second period.

The evidence obtained from English data with regard to the higher proportion of masculinity in the rural areas as compared with urbanized centres does not stand alone. It is supported by the available statistics in the United States where the sex ratios in the urban and in the rural areas during the period 1927–9 were $1057 \pm 1{\cdot}20$ and $1064 \pm 1{\cdot}15$ respectively, the difference $7 \pm 1{\cdot}66$ in favour of the rural areas being greater than would be expected to arise by mere chance. A possible explanation of the higher sex ratios of live births in rural areas as compared with urban centres is a probable lower incidence of abortions in the former, superadded to the undoubted fact that the proportion of still births to total live births is lower in the country than in the town.

ILLEGITIMACY

Some investigators have stressed the fact that the sex ratio of illegitimate births is smaller than that of live births. Heape (1909), in his study of live births in Cuba for the period 1904–6, obtained the following results:

	Legitimate	Illegitimate
White population	1078	1044
Coloured population	1068	968

From these values he concluded that "it is clear that illegitimate union among civilized peoples is due to individual characteristics in the woman which have for their basis a specially active sexuality. Thus the result of illegitimate union, the increased production of females in consequence thereof, is an individual matter, it cannot be accounted for by any law of heredity and must be associated with physiological conditions which induce this special activity, that is to say with forces which affect the metabolic activity of the woman."

The invocation of biological principles as an explanation seems unnecessary. A simpler and probably a more adequate description is a presumably greater relative incidence of abortions and miscarriages amongst unmarried than amongst married women, and amongst the coloured than amongst the white population. On this basis the differences observed by Heape arise as the result of a pre-natal mortality in which there is a large male excess.

The sex ratios of the illegitimate births in this country differ appreciably from those for Cuba, the values for the two decennia 1911–20 and 1921–30 were:

	1911–20	1921–30
Legitimate	$1044{\cdot}0 \pm 0{\cdot}82$	$1045{\cdot}2 \pm 0{\cdot}82$
Illegitimate	$1043{\cdot}7 \pm 3{\cdot}5$	$1040{\cdot}7 \pm 3{\cdot}5$

The index for illegitimate births was almost identical with that for legitimate births during the first decennium and, in the second period, the observed difference lies within the error of random sampling.

An interesting feature of the sex ratios of illegitimate children, but not quite relevant to the present study which mainly concerns live births, was indicated by the late Dr Stevenson in the statistics for 1928. He showed that the sex ratio of the deaths of illegitimate children who died in the first 30 min. after birth was dominantly female, the value being 0·868. To ascertain whether this was an isolated event or characteristic of subsequent years also, the data for the period 1929–33 were examined. The ratio obtained was 1·050 and thus indicates that the 1928 experience was an abnormal one.

Seasonal variation

In the literature on the sex ratio there is little or no evidence of any definite seasonal variation. The statistics of England and Wales for each year between 1921 and 1933 confirm this (Table VII). To minimize the effects of

Table VII. *Showing the seasonal incidence of the sex ratio at birth in England and Wales and in the United States*

	England and Wales, 1921–33		United States: All cities, 1921–24		United States: All rural districts, 1921–24		City of New York, 1929–1933	
Quarter	Total births	Sex ratio	Total births	Sex ratio	Total births	Sex ratio	Total births	Sex ratio
1st	2,531,259	1048 ± 1·32	925,318	1050 ± 2·19	907,342	1056 ± 2·22	258,564	1051 ± 4·13
2nd	2,592,588	1045 ± 1·30	904,224	1061 ± 2·23	893,615	1063 ± 2·25	259,772	1060 ± 4·16
3rd	2,499,267	1047 ± 1·33	948,752	1057 ± 2·16	918,869	1061 ± 2·22	265,136	1056 ± 4·10
4th	2,295,899	1047 ± 1·38	876,038	1054 ± 2·26	838,274	1058 ± 2·30	243,465	1053 ± 4·28

chance fluctuations the ratios were calculated for quarterly instead of for monthly periods. The index was 1048 ± 1·32 for the first quarter, it declined to 1045 in the second quarter, and remained at 1047 for the rest of the year. The decreased ratio in the second quarter might appear to suggest that when conception occurs between July and September the resultant sex ratio at birth is less favourable to the males. The difference, however, between the highest and lowest index is not statistically sensible.

While the results for England and Wales support the general belief in absence of any seasonal correlation, those for the urban and rural divisions of the United States for the period 1921–4 and for New York City during 1929–33 reveal evidence of a definite trend. In each area the sex ratio is lowest in the first quarter, attains its maximum in the second (when the English index is lowest), and then gradually declines. The difference between the size of the indices in the first and second quarter for the urban and rural areas is of statistical significance but not quite so for New York City. Hence the American statistics, contrary to the experience in England, support the view that conception during July to September is favourable to increased

masculinity. In explanation of this difference between the seasonal distribution of the sex ratios of births in the two countries it might be suggested that it results merely from a corresponding divergence in the seasonal distribution of marriages. To test this the total marriages for the period 1921–34 were classified in quarters January to March, etc., and the percentage in each quarter calculated. The data for the Registration Area of the United States not being available the marriage statistics for New York State were used as a criterion of the American experience. The results were:

	England and Wales	New York State
	%	%
January–March	17	16
April–June	26	28
July–September	31	30
October–December	26	26
	100	100

As there is no apparent difference in the seasonal distribution of marriages in the two countries it follows that the divergence in the seasonal incidence of the sex ratios of the live births must be due to some other cause.

SEX RATIO IN VARIOUS COUNTRIES

To obtain some idea of the prevailing range in the sex ratio in the different countries of the world the male and female births in forty-two countries were extracted from the *Annuaire de Statistique* and the indices calculated. The data relate mainly to the years 1921–9. In some instances the records for all the years were not available, but the period was never less than 5 years in any country. The indices are classified according to their size in Table VIII,

Table VIII. *Showing the size of the sex ratio at birth in various countries*, 1921–9

Sex ratio	Frequency	
1030–	1	Salvador
1040–	5	Japan (1043)
1050–	13	
1060–	15	
1070–	1	
1080–	4	
1090–	1	Argentine
1100–	—	
1110–	—	
1120–	—	
1130–40	2	Greece and Korea
	42	

and the names of the countries with very low or very high ratios indicated. The country which had the lowest index was Salvador, 1030, with Japan next, 1043. At the other end of the scale we find Korea with a sex ratio of 1131 and Greece 1132. The range in the size of the sex ratios in these four countries is not attributable to smallness of the population on which the

indices were based, as the total births recorded for each country during the period in question were:

Korea ...	...	5,340,868	Japan	...	16,389,791
Salvador	...	528,511	Greece	...	1,160,506

It may be argued that the values in Salvador and Korea are unreliable owing to the possible imperfection in the registration of their vital statistics. This suggestion may be perfectly true, but, on the other hand, there is no reason why, if there be inaccuracy in the entry of birth, the sexes should not be equally affected. Of course, it may well be that less importance is attached to female life in some countries than in others, and, as a consequence, the registration of female births in such countries is defective. The Korean experience is in agreement with such a hypothesis; but on what basis can the low value in Salvador be explained? The mean index for the forty-two countries was 1065 and the dispersion around this mean was 19·88. From this it will be observed that the indices in both Greece and Korea are exceptionally high, as they lie outside the limit of three times the standard deviation around the mean. To ascertain if the experience of these countries in recent years with regard to the size of the sex ratio at birth also characterized their past history, the indices recorded by Lewis for nineteen of these countries during the four years 1887–91 were correlated with the corresponding values for the decennium 1921–30. The coefficient was $+0{\cdot}902 \pm 0{\cdot}043$, from which we infer that there either has been little modification of the sex ratio in these countries during a period of 40 years or else the trend in each of the different countries has been remarkably uniform.

Cross-breeding and migration

There is, however, some evidence to the effect that the sex ratio of a country may be influenced by cross-breeding and migration. The researches of S. Gache (described by Lewis and Lewis in their book—*Natality and Fecundity*) amongst the population of Buenos Ayres have shown these factors to be of some importance. The births as the result of unions of Italian, Spanish and French male emigrants with Argentine females had a higher masculinity than that produced either by (1) pure Argentine alliances or (2) by pure alliances of any of these nations in Buenos Ayres. Further, he found that Italians married to Italians but resident in Buenos Ayres had a lower sex ratio than Italians in their home country. In Italy the masculinity was 1060, whereas the Italians in Buenos Ayres had a sex ratio of 1042. Among Spaniards the corresponding ratios were 1083 and 1028; and amongst the French 1046 and 1036. There is, thus, some evidence that migration appreciably modified the sex ratio at birth for these three Latin races.

We can test the importance of this migratory aspect and also the effects of cross-breeding in a study of more recent statistics in the United States, as

in that country the births are classified according to the nationality of the parents. The sex ratio of children born during 1921–4 to parents of European stock resident in the United States is given in Table IX. There is a fair amount

Table IX. *Showing* (1) *the sex ratios at birth of children born to emigrants in the United States during* 1921–4 *and* (2) *the corresponding indices in their homeland during the same period*

	Nationality				
Nationality of mother	Father's same as mother	Father foreign	Nationality of father	Mother foreign	Homeland
Austria and Hungary	1063 (171,637)	1071 (36,909)	Austria and Hungary	1080 (47,464)	1067
Denmark, Sweden and Norway	1073 (35,599)	1051 (18,799)	Denmark, Sweden and Norway	1062 (40,578)	1058
Germany	1065 (21,772)	1069 (29,543)	Germany	1062 (51,666)	1070
Italy	1035 (378,420)	1093 (11,380)	Italy	1038 (87,259)	1052
Russia and Poland	1060 (313,432)	1058 (43,345)	Russia and Poland	1064 (99,347)	1064

Figures in brackets are the total numbers of births.

of evidence deducible from the results in this table to support the claim that the proportion of male children born to migrant parents is lower than that in the homeland. The sex ratio at birth in Austria and Hungary during 1921–4 was 1067, whereas that resulting from alliance of these nationals with each other in the United States during the same period was 1063. For parents of German nationality the corresponding values were 1070 and 1065, and for Russians and Poles 1064 and 1060. More pronounced was the Italian experience. The sex ratio at birth in Italy was 1052, but for Italian nationals resident in the United States the index was as low as 1035.

The only exception to this trend of a reduced masculinity when the parents live outside their national frontiers is that for the composite group of northern countries, Denmark, Sweden and Norway. The sex ratio of the births was higher for the migrant population than for that in the homeland.

The effects of cross-breeding on the sex ratio are not readily discernible in the present data. The only clearly demonstrable instance is that in which the parents are of Austrian-Hungarian nationality. The masculinity is higher when either one or other parent is of this nationality than when both of them are. For parents of German, Italian and Russian origin the results do not consistently support the hypothesis that cross-breeding reduces the sex ratio at birth, whilst the experience of migrants from Denmark, Sweden and Norway shows that the highest proportion of male births accrue when both the father and mother are of the same nationality.

Effects of war

The statement has sometimes been made that the sex ratio at birth is influenced by social upheavals. It is said that after the termination of a war and the return of soldiers to their homes the births in the subsequent year or years contain an increased proportion of males. Knibbs (1917), on the other hand, has shown clearly that the French birth statistics were uninfluenced by such events. The indices before and after 1870–1 revealed no change in the masculinity.

The history of the sex ratio during 1915–18 and in the post-war years 1919–20 and 1921–3 affords a more reliable basis than has hitherto been available for determining this aspect of the problem. The indices in each of nineteen countries, twelve of which were participants in the Great War and seven neutral, were calculated for the periods in question. The results are given in Table X. The outstanding feature of this table is the increased masculinity in the immediate post-war years 1919–20, and it is characteristic of the warring and neutral nations alike but the more strongly indicated in the former. The unweighted mean sex ratio in the neutral countries was 1061 during 1915–18, 1067 in 1919–21 and 1062 during 1921–3, whereas the corresponding ratios for the other group of nations were 1058, 1069 and 1058.

To illustrate the position in a more detailed manner the sex ratios of the quarterly births in England and Wales during each year from 1915 to 1921

Table X. *Showing the sex ratio at birth of* (1) *countries engaged in the past war and* (2) *of neutral countries*

Country	Period 1915–18	Period 1919–20	Period 1921–23
(1)			
Germany	1064	1075	1070
Austria	1053	1070	1061
Belgium	1050	1062	1053
Bulgaria	1069	1076	1062
France	1052	1061	1050
United Kingdom	1047	1055	1048
Hungary	1068	1076	1070
Italy	1054	1059	1052
Roumania	1051	1064	1063
Australia	—	1061	1056
New Zealand	—	1062	1059
South Africa	1076	1103	1051
Mean	1058	1069	1058
(2)			
Denmark	1053	1054	1059
Spain	1098	1098	1094
Finland	1060	1067	1061
Norway	1053	1069	1050
Sweden	1057	1064	1059
Switzerland	1052	1055	1052
Pays Bas	1058	1065	1058
Mean	1061	1067	1062

were calculated and they are given in Table XI. With the exception of the first quarter of 1915 the indices were of the normal order for the rest of that year. There was a decided increase in 1916 in each quarter apart from the

Table XI. *Showing the sex ratio at quarters of the year in England and Wales between* 1915 *and* 1921

Quarter	1915	1916	1917	1918	1915–18	1919	1920	1921	1919–21
1st	1031	1050	1042	1043	—	1059	1054	1048	—
2nd	1042	1051	1042	1046	—	1052	1048	1057	—
3rd	1044	1045	1043	1048	—	1057	1050	1050	—
4th	1043	1050	1049	1056	—	1067	1058	1047	—
Annual value	1040	1049	1044	1048	1045	1060	1052	1051	1054

third, but, during 1917, the ratios reverted to normality. In the last quarter of 1918 the ratio was definitely in excess of any previous value. There is no apparent reason for this sudden increase in the index, but the history of the subsequent high ratios, particularly in 1919, can be readily associated with the demobilization and the return of the soldiers to their homes.

SOCIAL STATUS

Attempts have been made in the past to correlate the sex ratio at birth with the social status of the parents. Lewis classified his Scottish data according to the father's occupation and showed that the index for the professional classes was low, whereas that for the agricultural workers and seafarers was high. A similar trend was observable in the Swedish statistics for 1851–60. But, generally speaking, where the correlation between these variables has been attempted the data were inadequate for a satisfactory description of the relationship. The available information in England and Wales is better suited for this purpose. In Part II of the *Decennial Supplement* for 1921, the Registrar-General classified the births, male and female, for the year 1921 according to the social position of the father. Accepting Class I (upper and middle), Class III (skilled workers) and Class V (unskilled workers) as representing well-defined zones of social conditions we find that the sex ratio in each was:

	Sex ratio	S.E.	Number of births
Class I	1061	±19·04	12,404
Class III	1057	± 3·39	365,337
Class V	1034	± 5·80	122,940

We thus have fairly reliable evidence that masculinity decreases with descent in the social scale. The difference between Classes I and III is not statistically significant, but that between Classes III and V is definitely so. We can measure the degree of relationship between these two variables from another angle. Accepting the size of the infantile mortality rate as the best available index of social conditions we can correlate it with the corresponding sex ratio at birth. When this was done for the London Boroughs for the decennium 1911–20 the coefficient was $r = -0{\cdot}497 \pm 0{\cdot}142$, which is statistically significant

and indicates that the sex ratio declines as social conditions become worse. In other words it corroborates the evidence revealed by the data for Social Classes I, III and V.

The sex ratio of the births in peerage families is also very high:

Period	Number of births	Sex ratio
1700–50	2,181	1214
1750–1800	8,403	1185
1800–50	10,616	1099

but this particular aspect of peerage statistics must be accepted with reserve. Most peerage families descend through male heirs, and the record of male births would be of family importance. Such a consideration would, of course, tend to bias the entries in favour of the males and so produce high sex ratios.

It might be that the higher sex ratios of the births in the best social classes is due to the fact that the size of families in this grade is small and, as we shall see in the subsequent section, there is a higher degree of masculinity in small families than in large ones.

Primogeniture

The statistics hitherto tabulated on the sex ratio of firstborn children support the viewpoint that the masculinity is higher amongst them than amongst subsequent births. Knibbs (1917) found that the index of the firstborn in Australia for the years 1908–13 was 1052·6 as compared with 1050·0 for later births. Lewis, in his Scottish data, obtained 1054 and 1048 respectively. In view of this evidence of a higher sex ratio amongst the firstborn it is of interest to study the birth statistics in more detail to see if a continuous decrease in masculinity is associated with increasing size of family. For this purpose the data in the United States for the years 1927–9 were examined, as, in that country, the sex of a child and its order of birth in family are published in the official returns. The births registered during this period numbered more than 6,000,000, and hence the results in Table XII, since

Table XII. *Showing the sex ratio at birth according to size of family in the United States during* 1927–9

Birth	Sex ratio	S.E.	Birth	Sex ratio	S.E.
1st	1061	±1·6	6th	1054	±3·8
2nd	1060	±1·8	7th	1051	±4·4
3rd	1058	±2·2	8th	1050	±5·1
4th	1055	±2·7	9th	1052	±6·2
5th	1051	±3·2	10th	1051	±4·7

they are based on large numbers, are fairly reliable and not likely to be much influenced by random fluctuations. As will be noted in the table the index steadily decreases between the first and the fifth birth, the respective values being 1061 and 1051. The ratio for the sixth birth is higher than that for the fifth, but the trend for families containing more than six children is slightly

irregular. Owing to this irregularity it is difficult to state the exact equation which represents the relationship between the two variables but, undoubtedly, it is of an exponential character.

The decrease in the size of the sex ratios of live births with the increase in the size of family is clearly demonstrated in the statistics. But what are the factors which produce such a result? Does a woman tend to have relatively fewer male births as the number of her conceptions increases? Is this observed reduction in masculinity simply the result of a relatively greater incidence of miscarriages and abortions (which are generally accepted as being predominantly male) in the larger families? If it is attributable to the former then we should expect a similar negative relationship observable in the corresponding sex ratios of still births.

The statistics of male and female still births according to size of family are available in the *Annual Reports of the United States Department of Commerce, Bureau of the Census since* 1922. Unfortunately the author did not have the particulars for the complete period between 1922 and 1929—the years 1925 and 1926 were missing. Incorporating the remainder of the series, that is the years 1922–4 and 1927–9, there are records of 232,177 male and 171,172 female still births. The sex ratios of these according to size of family were as follows (the sex ratios of the live births are placed in apposition for purposes of comparison):

	Number	Still births Sex ratio	Live births Sex ratio
1st child	135,943	1351·6	1061·1
2nd child	67,452	1350·0	1060·0
3rd child	46,589	1351·4	1058·1
4th child and upwards	153,365	1365·0	1052·3

There is no similarity in the trends and this suggests that decreasing masculinity with increased size of family for live births must be explicable on grounds other than a declining capacity of the woman to produce male births. Otherwise, the trend of the curve of the sex ratios for live births should approximate to that for the sex ratios of still births. Can it be then that the second hypothesis—a possible higher incidence of miscarriages and abortions in large-sized families than in small families—is the explanation? Unfortunately there are no statistics available which will permit an analysis.

PARENTAL AGE

The relationship between the parental age and the sex ratio at birth has been made the subject of a very careful and detailed study by Wicksell (1926, 1926*a*). He examined the data for Berlin, the Netherlands and Norway and found that in Berlin the sex ratio for certain pre-war periods was correlated with the age of the father (it decreased with age) but it was less associated with that of the mother. In the immediate post-war years, 1919 and 1920–2, a very remarkable change occurred and it is described by Wicksell as follows: "For both parents, but in particular for the mother, we found that the year

1919, when the total sex ratio reached its maximum, is characterized by a remarkable rise of the sex ratio in the youngest and oldest classes while the rise is more moderate in middle ages. But in 1920–2 the sex ratio of the young parents, father as well as mother, has returned to a more normal state while it still continues to rise when the parents are older especially when the mother is above 40 years of age. Although the figures for 1919 are not quite significant, if taken each by itself their trend is so systematical, both for fathers and for mothers, that there can be hardly any doubt about the reality of this phenomenon." It is impossible to say whether the changes in the sex ratio obtainable from the Berlin data occurred also elsewhere as the statistics for so long a period are not available and, in point of fact, the age of the parent is not inserted on the birth certificate in most countries. This practice is, however, adopted in the United States, and the sex ratio according to the parents' age for the period 1921–4 is given in Table XIII. It will be noted that for specific

Table XIII. *Showing the sex ratio of births according to the ages of the father and the mother in the United States Registration Area for the period* 1921–4

Father's age	Mother's age						All ages of mother
	15–20	20–25	25–30	30–35	35–40	40–45	
15–20	1064 ± 8·81	1068 ± 17·89	1105 ± 70·73	—	—	—	1065 ± 7·78
20–25	1061 ± 3·57	1063 ± 2·64	1075 ± 7·47	1072 ± 23·83	1101 ± 57·78	1168 ± 142·44	1063 ± 2·04
25–30	1062 ± 5·34	1057 ± 2·30	1061 ± 2·45	1055 ± 6·78	1086 ± 20·26	1147 ± 67·20	1059 ± 1·54
30–35	1046 ± 10·50	1063 ± 3·86	1057 ± 2·53	1057 ± 2·94	1057 ± 8·06	1070 ± 29·39	1058 ± 1·65
35–40	1024 ± 18·38	1052 ± 7·04	1056 ± 4·01	1044 ± 3·07	1061 ± 3·73	1037 ± 12·73	1053 ± 1·93
40–45	1130 ± 37·70	1038 ± 13·12	1056 ± 7·85	1047 ± 5·02	1053 ± 4·09	1049 ± 6·19	1050 ± 2·58
45 +	1015 ± 38·49	1058 ± 17·41	1054 ± 10·68	1044 ± 7·40	1059 ± 5·33	1054 ± 5·75	1053 ± 3·08
All ages of father	1059 ± 2·57	1059 ± 1·52	1059 ± 1·52	1052 ± 1·81	1058 ± 2·30	1052 ± 4·00	1057 ± 0·78

age of father irrespective of that of the mother the index decreases with age. When the father is aged 20–25 years the ratio is $1063 \pm 2{\cdot}04$, and it declines to $1050 \pm 2{\cdot}58$ when the age is 40–45 years. The only exception to this decrease with age is for fathers over 45 years when their index is greater than that in the immediately preceding group, but the difference may be a pure chance event. This association of a declining index with increasing age of father is also evident when allowance is made for age of the mother as is done in the body of the table. On the other hand, the sex ratio has no apparent association with the mother's age as the trend is irregular, static at 1059 for mothers between the ages of 15 and 30 years, and oscillatory afterwards. On the whole the American experience for the period 1921–4 bears a certain resemblance to that in Berlin during 1878–95, inasmuch as the sex ratio is more correlated with the father's age than with that of the mother.

This lack of association between the sex ratio and the mother's age was also apparent in the investigation made by Ewart (1915). He found that the zero correlation between the age of the mother at the birth of offspring and the sex ratio was $r = -0{\cdot}055 \pm 0{\cdot}011$, and the partial correlation with the sequence of birth made constant was $r = -0{\cdot}06 \pm 0{\cdot}01$. This coefficient, although significant when expressed in terms of its standard error, is in itself too small to be of any consequence.

RELATIONSHIP TO BIRTH-RATE

To what extent is the size of the sex ratio correlated with movements in the birth-rate? Does a high or low birth-rate produce a high or low masculinity index? These are questions which merit full consideration. In this country the birth-rate has decreased by at least 50 per cent. since 1875—when compulsory registration of births was instituted. In view of this it is of interest to measure the degree of parallelism in the trend of the two variables. Accordingly the annual fluctuations in the birth-rate during the period 1875–1932 (the year 1920 was regarded as abnormal and omitted) were correlated with the corresponding variations in the sex ratios, and the result was $r = +0{\cdot}216 \pm 0{\cdot}126$. The coefficient is fairly small, but it suggests that there is a slight conformity in their secular trend—years in which the birth-rate either increased or decreased, being also characterized by slight but similar oscillations in the size of the sex ratio. To assess the spatial relationship the birth-rate and the corresponding sex ratio within the different administrative areas of England and Wales during the period 1911–20 were correlated and the results were:

London Boroughs	...	...	$r = -0{\cdot}287 \pm 0{\cdot}174$
County Boroughs	...	...	$r = -0{\cdot}190 \pm 0{\cdot}107$
Urban Districts...	...	...	$r = +0{\cdot}173 \pm 0{\cdot}124$
Rural Districts ...	...	...	$r = +0{\cdot}189 \pm 0{\cdot}125$

It will be noted from these coefficients that a spatial correlation based on the aggregated experience of the whole country would misrepresent the actual relationship, as although the coefficients are not statistically significant, any association that exists is determined to some extent by the type of area. In the more highly urbanized districts the association is of an inverse character—fairly low masculinity accompanying a fairly high birth-rate, the correlation in London being $-0{\cdot}287$ and in the county boroughs $-0{\cdot}190$. For the small urban districts and for the rural areas the correlation, on the other hand, is positive and is slightly greater for the latter than for the former.

SEX RATIO OF STILL BIRTHS

One of the indisputable facts in vital statistics is that in infancy the male death-rate exceeds that of females. The high sex ratio of this mortality is commonly believed to characterize the pre-natal experience (where pre-natal indicates birth before full-time delivery) in a still more striking manner. There are, however, no statistics on the complete ante-natal phase, as abortions are not recorded. The registered particulars relate solely to still births which, in England and Wales during the period 1928–32, yielded a sex ratio of 1225 as compared with 1047 for live births. There is thus an excess difference of 17 per cent. in favour of the former.

Owing to this differentiation in the size of the sex ratio of live and still births one might suppose that since the former represents the residuum of the conception ratio there would be a fairly high negative correlation between it and the proportion that still births bear to the total live births. There is, however, little or no evidence of any appreciable degree of correlation in the data for (1) the English and Welsh Counties and (2) the Boroughs of London during the period 1928–32, as the coefficients are $+0{\cdot}112 \pm 0{\cdot}130$ and $+0{\cdot}211 \pm 0{\cdot}183$. The size and sign of the coefficients are obviously contrary to what one would expect. But it is of interest to note that the experience throughout the country generally is confirmed by that in the London Boroughs where there is probably a fairly accurate recording of still births.

In view of this slight association it was futile to attempt a prediction of the pre-natal index from a knowledge of the ratio of live births much less from that of the subsequent infantile mortality sex ratios. But, despite this, we may ask if there is any alteration in the size of the still birth sex ratio during the various stages of the uterogestation period. It is impossible to obtain statistics on an extended scale which will enable a definite answer to be given. We can, however, give an approximate assessment. The statistics of male and female still births according to the duration of pregnancy are recorded in the *Annual Reports* for a particular area[1] composed of certain specified registration states and cities in the United States. The data for the years 1926–9 were extracted and relate to a total of 77,373 still births, classified in single months after the fourth month of pregnancy. As the numbers in some months were small, they were regrouped into wider intervals and the calculated values, in addition to those obtained from the live births and the infantile deaths during the same period of years, 1926–9, are given in Table XIV. The total still birth sex ratio in this area was 1345 as compared with 1056 for live births, and it varied considerably according to the duration of pregnancy. When the uterogestation period was less than 4 months the index was as high as 3755; in the next interval 4–6 months there was a considerable decrease, the ratio being 1426 and in the period 7–9 months there was a further decline, 10 per cent. The low index in the last period 7–9 months, 1293, is contrary to general impression, as it is generally believed that the masculinity is of a very high order at this stage, particularly at the seventh month. The individual monthly ratios (not given in the table) do not support this belief. At the fourth month the ratio was 2137, and at the seventh it was the lowest obtained at any period, 1153. According to the present experience, the masculinity of still births during the fourth to the ninth month of the uterogestation period approximated to that for the total infantile deaths, the respective ratios being 1322 and 1341. But caution must be exercised in drawing any conclusions concerning the relationship between the pre-natal and post-natal indices of masculinity as determined by the sex of

[1] Connecticut, Illinois, New Jersey, New York State, Oregon, Utah, Washington District of Columbia and Baltimore, Md.

Table XIV. *Showing the sex ratio of still births and infantile deaths in a particular area in the United States during* 1926–9

	Uterogestation period
Under 4 months	3755
4–6 months	1426
7–9 ,,	1293
4–9 ,,	1322
Total still births	1345
Total live births	1056
	Infantile deaths
Under 1 day	1349
1–2 days	1348
2–3 ,,	1535
3–6 ,,	1435
Under 1 week	1383
1–2 weeks	1293
2–3 ,,	1172
3–4 ,,	1360
Under 1 month	1353
1–2 months	1408
2–3 ,,	1372
3–6 ,,	1322
6–9 ,,	1338
9–12 ,,	1177
Under 1 year	1341

still births and live births. We must not lose sight of the fact that the number of still births does not constitute the total loss of life in the pre-natal phase. Abortions, which are not registered, probably outnumber the still births rather considerably, and, occurring as they do in the early months of pregnancy, are generally accepted as being predominantly male.

CONCLUSIONS

1. The high sex ratios of the births in the initial years of registration in England and Wales (Table III) possibly represent the continuance of a secular trend at a higher level. The large indices obtainable from such pre-registration data as the male and female christenings in London for the period 1629–1849 (Table IV) and the male and female births in Peerage families between the seventeenth and nineteenth century point in this direction.

2. The sex ratio at birth has no geographical significance in England and Wales as the values in different sections of the country do not differ appreciably (Table V). The ratio is, however, influenced by urbanization, being significantly lower in the county boroughs than in the rural areas (Table VI). This association is also evident in the urban and rural areas of the United States. The explanation may well be that abortions are in all probability relatively much more frequent in towns and, being as is generally supposed largely male, the sex ratio of full time deliveries in urban centres is in consequence understated.

3. The sex ratio shows no seasonal variation in England and Wales but, in the United States, it is definitely highest in the second quarter of the year (Table VII).

4. In some countries, particularly in Greece, the masculinity at birth is exceptionally high; in others—Japan and Italy—rather low (Table VIII), and there is evidence that it may be influenced by such a factor as migration. Births accruing from marriages of the same nationals resident outside their own country have, in some nationalities, a lower sex ratio than that which occurs in the homeland. There is no satisfactory evidence that marriage of different nationals, or what may be termed cross-breeding, influences the sex ratio, as was indicated by Gache in his study of the population of Buenos Ayres.

5. Social upheavals influence the index. In those countries which were directly engaged in the Great War the sex ratio was high in the years immediately succeeding the close of hostilities. It was higher after the termination than during the war. Neutral countries experienced the same phenomenon but not to such an appreciable degree (Tables IX and X).

6. The ratio is highest amongst firstborn children and declines with increasing size of family in a curvelinear manner (Table XII), but the sex ratio for still births and size of family has an entirely different trend.

7. The ratio in England and Wales is definitely correlated with Social Status—the index decreases in size with descent in the social scale. The correlation may merely be due to the fact that in the higher social class the size of families is relatively small and in small families the sex ratio of births is high.

8. There is no conclusive evidence that the sex ratio is related to the age of the parents but, any relationship which may exist, is with the age of the father rather than with the age of the mother (Table XIII).

9. The sex ratio of still births, which is approximately 20 per cent. higher than that of live births in England and Wales, varies considerably according to the period of uterogestation. In a particular area in the United States it was as high as 3755 for pregnancies under 4 months' duration, and it declined to 1293 when the period was 7–9 months (Table XIV). There is, however, no appreciable correlation between the sex ratio of live births and the proportion of still births to total births. The coefficients for the counties of England and Wales and for the boroughs of London in the period 1928–32, $r = +0{\cdot}112 \pm 0{\cdot}130$ and $0{\cdot}211 \pm 0{\cdot}183$ respectively, lie within the errors of random sampling.

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