AN ASSOCIATION BETWEEN RAINFALL AND SEX RATIO IN MAN

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Summary. Seasonal variations in secondary sex ratio in man in Perth, Adelaide and Brisbane appear to be influenced by seasonal variations in rainfall. In these cities, the onset of the rainy season is followed about 11 months later by a larger than normal excess of male births. Sex ratio in Sydney, however, where rainfall is more evenly distributed throughout the year, does not vary markedly with season; but a relationship between rainfall and sex ratio again becomes apparent when the data are analysed in terms of wet months and dry months and of wet years and dry years. It is suggested that secondary sex ratio is affected by properties of drinking water that alter with variations in rainfall, and that the property of water concerned is probably its content of trace elements. Support for this hypothesis has been obtained from an examination of sex ratios in two regions of Australia with trace-element deficiencies. It is also suggested that drinking water exerts its effect through the male parent and that the observed variations in secondary sex ratio reflect similar variations in primary sex ratio.

INTRODUCTION

In mammals, sex is genetically determined at fertilization and depends upon whether the fertilizing spermatozoon carries an X (female-determining) chromosome or a Y (male-determining) chromosome. For convenience, the two kinds of spermatozoa can be referred to as X- and Y-spermatozoa. In theory, meiosis during spermatogenesis ensures that X- and Y-spermatozoa are produced in equal numbers; hence, if each kind is equally competent to reach and fertilize the eggs, the sex ratio at fertilization (the primary sex ratio) will be unity. If male and female zygotes are equally viable *in utero*, the sex ratio at birth (the secondary sex ratio) will also be unity.

In man, secondary sex ratio in most countries displays a slight excess of males: in Australia, among live births, there are about 105·3 males to 100 females; in England and Wales there are about 105·8 males to 100 females. There is also evidence that this ratio varies systematically in different populations of births. Variation of this kind has been claimed, for example, between

births of different birth order, between legitimate and illegitimate births, between births at different seasons, between births in different countries and regions of the same country, between different social classes and different races, between births in rural areas and those in urban areas, and between births in time of war and those in time of peace (see Crew, 1952; Colombo, 1957). Some of these differences have been claimed to be statistically significant, but often other observations have given rise to contrary findings and in no case has a causal influence on sex ratio variation been unequivocally demonstrated. It is widely believed, however, that variation in secondary sex ratio reflects variation in the greater susceptibility of males to prenatal death rather than variation in primary sex ratio. According to this view, higher incidences of prenatal death are associated with higher losses among males than among females, and hence with lower secondary sex ratios. Some workers, however, believe that the determination of primary sex ratio is to some extent labile and that variations in secondary sex ratio reflect this lability. Both beliefs suggest that the primary sex ratio, which unfortunately cannot be measured, must depart from unity in favour of an excess of males, and this implies that Y-spermatozoa are either more effective in fertilizing eggs, or are produced in greater numbers, than X-spermatozoa. Natural selection will, of course, tend to ensure that the sex ratio will be optimal, presumably unity, at reproductive age, and if one sex is more vulnerable than the other during prepuberty a compensating adjustment in primary sex ratio is to be expected.

This paper gives evidence of systematic fluctuations of secondary sex ratio in Australia that appear to be associated with variations in rainfall. It is suggested that the rains influence sex ratio by altering the properties of drinking water, and that the content of trace elements is the property most likely to be involved. Evidence consistent with this thesis has been obtained by an examination of sex ratios in two areas of Australia with known trace element deficiencies. It is also suggested that the rains (or trace elements) exert their effect on sex ratio through the male parent, and that the observed variation in secondary sex ratio reflects variation in primary sex ratio.

SOURCES OF INFORMATION

The figures of monthly rainfall for Perth, Adelaide, Brisbane and Sydney, given in Table 1, have been taken from the 1961 edition of the *Yearbook of the Commonwealth of Australia* (Government Printer, Canberra). Rainfall for these areas has changed but little since 1941, and the 30-year averages for 1911 to 1940 are still accepted as the official averages. Information on rainfall used in compiling Table 7 was taken from the unpublished monthly readings for the Cordeaux Dam for the years before 1941, and from the weighted average for the whole catchment area compiled by the Metropolitan Water Board of Sydney for later years. With the exception of 1961, the rainfall registrations used in Table 8 are from the *Yearbook of the Commonwealth of Australia*: those for 1961 were obtained from the Commonwealth Bureau of Meteorology. These figures relate to Sydney itself and not the whole catchment area.

The monthly live birth registrations for Perth, Adelaide, Brisbane and Sydney, given in Tables 2, 3, 4, 6 and 7, are from unpublished figures provided

by the Commonwealth Statistician, Canberra. These registrations actually relate to the Metropolitan Divisions of Western Australia, South Australia, Queensland and New South Wales respectively: in each case the town contains most of the people in the Division. In Australia, registrations must be made within 60 days of birth and are not corrected for the actual date of birth; but, since certain social service benefits cannot be claimed before registration, the average delay between birth and registration probably is not more than 2 or 3 weeks. (Months in which public holidays fall, do, however, tend to show fewer births than full working months.) Only live births have been considered because figures for stillbirths are not available except for larger areas than this study deals with. (The incidence of stillbirths in the whole of Australia is now about 1.4 %. According to the *Statistical Register for New South Wales*, the incidence of stillbirths in the State of New South Wales for the 10 years 1951 to 1960 was 1.6 %, with a sex ratio of 114 males to 100 females.) The annual birth registrations for Brisbane and Sydney, used in Tables 5, 9 and 10, are from appropriate numbers of the *Bulletin of Demography* (Bureau of Census and Statistics, Government Printer, Canberra). The birth registrations used in Table 11 are from various issues of the *Statistical Register for New South Wales* (Government Printer, Sydney).

The significance of differences between estimates of sex ratio was determined by the chi-squared test.

TABLE 1

AVERAGE MONTHLY RAINFALL FOR PERTH, ADELAIDE, BRISBANE AND SYDNEY FOR THE YEARS 1911 TO 1940

	Rainfall (in.)			
	Perth	Adelaide	Brisbane	Sydney
January	0.33	0.76	5.72	3.86
February	0.50	1.10	5.47	3.15
March	0.90	0.87	4.97	4.44
April	1.75	1.45	3.68	5.65
May	5.14	2.49	2.35	4.98
June	7.55	2.93	2.75	3.68
July	7.08	2.49	1.88	4.89
August	5.78	2.58	1.07	2.41
September	3.37	2.39	1.69	2.77
October	2.30	1.54	2.27	2.80
November	0.75	1.22	4.00	2.54
December	0.54	1.27	4.24	3.63
Mean	3.00	1.76	3.34	3.73

OBSERVATIONS

Perth, Western Australia

Rainfall in Perth varies with season in a striking and predictable manner (Table 1, Text-fig. 1). The opening rains of the wet season begin in mid-April, when water supplies are at their lowest, and immediately create a high degree of turbidity (suspended matter) in the reservoirs. By the end of July, only the heaviest falls of rain can cause as much turbidity as a moderate fall in April.

The aggregated monthly registrations of live births for the period 1941 to 1962, classified according to sex, are set out in Table 2. The sex ratio for the months of March, April and May combined is significantly higher ($P < 0.01$) than that for the rest of the year. The month of conception for each sex ratio figure can be approximately determined by deducting 9 months from the month of birth registration. This adjustment shows that the high sex ratios result from conceptions in June, July and August, a period which extends from about

TEXT-FIG. 1. The monthly distribution of rainfall (solid lines), and of sex ratio at birth plotted at month of conception (broken lines), for (a) Perth, (b) Adelaide, (c) Brisbane and (d) Sydney. The data are taken from Tables 1, 2, 3, 4 and 6.

6 weeks to about 18 weeks after the onset of the wet season (Text-fig. 1). This seasonal variation in sex ratio is not associated with seasonal variation in total birth registrations, which are highest in October (conception month, January), although February (conception month, May) has both the lowest sex ratio and birth registration figures. Before 1940, however, there were no clear seasonal trends; until this time, Perth drew a large proportion of its drinking water from deep (2000 ft) artesian bores in limestone formations, and such water is likely to differ considerably from that obtained by surface drainage.

TABLE 2

AGGREGATED MONTHLY REGISTRATIONS OF LIVE BIRTHS FOR THE METROPOLITAN DIVISION OF WESTERN AUSTRALIA† FOR THE YEARS 1941 TO 1962

	Male births	Female births	Sex ratio (female = 100)
January	6510	6198	105.03
February	6115	5937	103.00
March	6491	6004	108.11*
April	6593	6183	106.65*
May	7277	6649	109.44*
June	6566	6221	105.55
July	6765	6440	105.05
August	7051	6738	104.67
September	6851	6553	104.55
October	7624	7209	105.76
November	6807	6431	105.84
December	6489	6232	104.12
Total	81139	76795	105.66

† Perth is the largest component of this division.

* The sex ratio for these months combined differs significantly from that of the other 9 months ($P < 0.01$).

Adelaide, South Australia

Adelaide also has a highly predictable seasonal variation of rainfall, but here the wet season usually starts at the beginning of May, and the total rainfall is much lower than at Perth (Table 1, Text-fig. 1). The catchment area for Adelaide's water supply was uniform until 1955, when considerable supplementation from the river Murray was started. This is a very large river which, with its tributary the Darling, drains a vast area of south-eastern Australia.

The aggregated monthly registrations of live births from 1911 to 1955 show a significantly higher sex ratio ($P < 0.01$) for the months of February, April, May and June than for the rest of the year (Table 3). The lowest sex ratio was recorded for January. The conception months for high sex ratio are May, July, August and September, of which the last three extend from about 8 weeks to about 20 weeks after the onset of the rainy season (Text-fig. 1). The high sex ratio for February is anomalous in this respect: it occurred in each of the decades between 1911 and 1955, and resulted from conceptions at the onset of

the rainy season just after the period when the water in the reservoirs was at its lowest.

Again, there is no significant relationship between seasonal variation in sex ratio and seasonal variation in total births registered, although the 2 months with lowest sex ratios (December and January) also have the lowest number of birth registrations. There has been no appreciable seasonal variation in sex ratio since the water supply was augmented from the Murray in 1955.

Brisbane, Queensland

In contrast to those of Adelaide and Perth, the wet season in Brisbane begins in mid-November and finishes in a rather indeterminate way between April

TABLE 3
AGGREGATED MONTHLY REGISTRATIONS OF LIVE BIRTHS FOR THE
METROPOLITAN DIVISION OF SOUTH AUSTRALIA† FOR THE
YEARS 1911 TO 1955

	Male births	Female births	Sex ratio (female=100)
January	10894	10558	102.9
February	11753	10876	108.0*
March	12944	12338	104.9
April	11666	10762	108.4*
May	12777	11918	107.2*
June	12642	11676	108.3*
July	12119	11411	105.9
August	12357	11876	104.1
September	13000	12224	106.4
October	12814	12083	106.1
November	12334	11831	104.3
December	10557	10238	103.1
Total	145857	137791	105.9

† Adelaide is the largest component of this division.

* The sex ratio for these months combined differs significantly from that of the other 8 months ($P < 0.01$).

and June (Table 1, Text-fig. 1). In recent years, there has been an increasing tendency, not clearly shown in the averages for 1911 to 1940, for the boundary of the southern winter rains to spread into southern Queensland during May, June and July.

During the years 1951 to 1962, the sex ratio for the months of November and December was significantly higher ($P < 0.001$) than for the rest of the year (Table 4). These high sex ratios result from conceptions in February and March, that is from about 10 weeks to about 18 weeks after the onset of the rainy season (Text-fig. 1). The lowest sex ratio was recorded for September (conception month, December). There is no evidence of any relationship between sex ratio and the number of births registered. Seasonal variations in sex ratio in Brisbane are, however, not apparent before 1951. There is evidence, moreover, that the annual sex ratio has not been constant throughout the period 1911 to 1962. The mean sex ratio for the 28 years 1925 to 1952 was lower than those for the preceding 14 years and for the subsequent 10 years (Table 5). Within

each of these three periods, annual sex ratios varied little, and from 1925 to 1952 only 5 years had a sex ratio above 106:100. The differences in annual sex ratio between the three periods accompanied changes in the management of the Brisbane water supply, especially the extent of chlorination, a factor which might well affect drinking habits. Water from the Brisbane river was

TABLE 4

AGGREGATED MONTHLY REGISTRATIONS OF LIVE BIRTHS FOR THE
METROPOLITAN DIVISION OF QUEENSLAND† FOR THE YEARS
1951 TO 1962

	<i>Male births</i>	<i>Female births</i>	<i>Sex ratio</i> (<i>female</i> = 100)
January	5264	5268	106.8
February	5202	4961	104.8
March	5758	5474	105.2
April	5350	5013	106.6
May	5877	5461	107.6
June	5483	5136	106.8
July	6097	5776	105.6
August	6084	5707	106.6
September	5929	5724	103.6
October	6184	5747	107.6
November	5769	5088	113.4*
December	5321	4838	109.8*
Total	68318	64193	106.4

† Brisbane is the largest component of this division.

* The sex ratio for these months combined differs significantly from that of the other 10 months ($P < 0.001$).

TABLE 5

CHANGES IN SEX RATIO FOR THE
METROPOLITAN DIVISION OF QUEENSLAND DURING THREE PERIODS BETWEEN
THE YEARS 1911 AND 1962

<i>Period of registration</i>	<i>Sex ratio</i> (<i>female</i> = 100)
1911 to 1924	106.4
1925 to 1952	105.2*
1953 to 1962	106.8**

* This ratio differs significantly from that of 1911 to 1924 ($P < 0.05$).

** This ratio differs significantly from that of 1925 to 1952 ($P < 0.01$).

first chlorinated at the end of 1923. From 1923 to the end of 1947, flocculation and filtration were inadequate, the water was very muddy during the wet season and chlorination was sometimes as high as 5 ppm. After new filter beds were installed in 1947 and 1954, chlorination was progressively reduced and since 1954 has not exceeded 1.5 ppm. Furthermore, before the construction of

the Somerset Dam, Brisbane had no proper reservoir: this dam came into partial use in 1943 and was completed in 1954.

Sydney, New South Wales

Rainfall in Sydney is more evenly distributed throughout the year than in the other three cities, and the mean monthly rainfall does not fall below 2.4 in. (Table 1, Text-fig. 1). The aggregated monthly birth registrations for the

TABLE 6
AGGREGATED MONTHLY REGISTRATIONS OF LIVE BIRTHS FOR
THE METROPOLITAN DIVISION OF NEW SOUTH WALES† FOR THE
YEARS 1911 TO 1962

	Male births	Female births	Sex ratio (female=100)
January	57799	55378	104.4
February	53964	50868	106.1
March	56950	54438	104.6
April	54637	51734	105.6
May	58479	55662	105.1
June	55585	53193	104.5
July	58902	56190	104.8
August	58392	56057	104.2
September	57607	54811	105.1
October	60461	57468	105.5
November	56996	53819	105.9
December	53437	50475	105.9
Total	683389	650093	105.1

† Sydney is the largest component of this division.

TABLE 7
AGGREGATED REGISTRATIONS OF LIVE BIRTHS FOR MONTHS
FALLING 11 MONTHS AFTER HIGH RAINFALL MONTHS (DESIGNATED
MANIFESTATION MONTHS) AND FOR THE REMAINING MONTHS, FOR
THE METROPOLITAN DIVISION OF NEW SOUTH WALES DURING
THE YEARS 1910 TO 1961

	No. months	Male births	Female births	Sex ratio (female=100)
Manifestation months	222	250726	237000	105.8*
Remaining months	402	432663	413093	104.7*

* These ratios differ significantly from one another ($P < 0.01$).

51-year period 1910 to 1960 correspondingly show only small seasonal variations in sex ratio (Table 6, Text-fig. 1). Nevertheless, an association between rainfall and sex ratio does become apparent when the figures are analysed in terms of wet months and dry months, and, since 1948, of wet years and dry years. Between 1910 and 1961, there were 222 months with a rainfall exceeding 3.5 in. In the months falling 11 months after each of these 222 months, there

was a significantly higher sex ratio ($P < 0.01$) than in the other 402 months (Table 7). During the same period, there were thirty-five occasions when drought or near-drought for 3 months or more was followed by at least 5 in. of rain: the average sex ratio for the 11th month after each of these occasions was 107:100. The Commonwealth Yearbooks record twenty-three dates since 1910 when phenomenally large rainfalls occurred at places sufficiently close to influence the catchment area of Sydney: the birth registrations for the months 11 months later give an average sex ratio again of 107:100. From 1948 to

TABLE 8
ANNUAL RAINFALL REGISTRATIONS FOR SYDNEY FOR
THE YEARS 1948 TO 1961

<i>Year</i>	<i>Rainfall (in.)</i>	<i>Year</i>	<i>Rainfall (in.)</i>
1948	38.83	1956*	67.33
1949*	66.26	1957	27.13
1950*	86.33	1958*	59.19
1951	53.15	1959*	59.67
1952*	59.19	1960	51.01
1953	40.86	1961*	57.08
1954	41.29		
1955*	72.46	Mean	55.67

* Years in which the mean rainfall of 55.67 in. was exceeded.

TABLE 9
ANNUAL SEX RATIOS FROM REGISTRATIONS OF LIVE
BIRTHS FOR THE METROPOLITAN DIVISION OF NEW
SOUTH WALES FOR THE YEARS 1949 TO 1962

<i>Year</i>	<i>Sex ratio (female=100)</i>	<i>Year</i>	<i>Sex ratio (female=100)</i>
1949	104.38	1957*	106.00
1950*	106.05	1958	103.07
1951*	106.24	1959*	106.64
1952	104.27	1960*	105.77
1953*	104.80	1961	104.45
1954	106.33	1962*	106.01
1955	104.58		
1956*	107.00	Simple mean	105.39

* Years after years in which the mean rainfall of 55.67 in. was exceeded. These are the 'manifestation years' of Table 10.

1961, there were 8 years in which the average rainfall of 55.67 in. was exceeded (Table 8). With one exception (1953), the years following each of these years had sex ratios above the simple average (105.35:100), whereas, again with one exception (1954), the remaining 6 years had sex ratios below the simple average. Further, the year with the lowest sex ratio (1958) followed the year of lowest rainfall (Table 9). The aggregated birth registrations for these two sets of years show a significant difference in sex ratio (Table 10).

Areas of Australia with trace-element deficiencies

Birth registrations have also been examined for two areas of Australia considered to be deficient in trace elements such as copper, zinc, molybdenum, sulphur and boron. These are the Tablelands of New South Wales, which

TABLE 10

AGGREGATED REGISTRATIONS OF LIVE BIRTHS FOR YEARS FOLLOWING YEARS OF GREATER THAN AVERAGE RAINFALL (DESIGNATED MANIFESTATION YEARS) AND FOR THE REMAINING YEARS, FOR THE METROPOLITAN DIVISION OF NEW SOUTH WALES DURING THE YEARS 1949 TO 1962

	<i>No. years</i>	<i>Male births</i>	<i>Female births</i>	<i>Sex ratio (female=100)</i>
Manifestation years	8	148100	139594	106.09*
Remaining years	6	108988	104308	104.49*

* These ratios differ significantly from one another ($P < 0.01$).

TABLE 11

REGISTRATIONS OF LIVE BIRTHS FOR LOCAL GOVERNMENT AREAS WITH LOW SEX RATIOS IN THE TABLELANDS OF NEW SOUTH WALES FOR THE YEARS 1927 TO 1962

	<i>Male births</i>	<i>Female births</i>	<i>Sex ratio (female=100)</i>
MUNICIPALITIES			
Bombala	619	612	101.1
Cooma	2000	1979	101.1
Goulburn	6422	6254	102.7
Camden	927	908	102.1
SHIRES			
Cudgegong	1628	1654	98.4
Abercrombie	1289	1320	97.7
Cockburn	1989	1988	100.1
Bibbenluke	1225	1219	100.5
Guyra	2985	2954	101.0
Lyndhurst	2624	2618	100.2
Merriwa	1238	1264	97.9
Molong	1943	1945	99.9
Manilla	1046	1043	100.3
Peel	2787	2782	100.2
Snowy River	1840	1822	101.0
Tallaganda	1052	1120	93.9
Wingecarribee	2475	2457	100.7
Wollondilly	3178	3122	101.8
TOTAL	37267	37061	100.6

extend from the Queensland border to the Victoria border, and a large part of the agricultural region in south-west Western Australia.

Birth registrations for New South Wales, published by municipality and shire, are available from 1916 (*Statistical Registers for New South Wales*). Up to 1926, however, births were classified according to the actual place of birth, and

the records are heavily biased in favour of towns with maternity hospitals. From 1927, births have been classified according to the usual residence of the mother, but analyses of the records remain difficult because of changes in the boundaries of the registration areas. The total birth registrations for the period 1927 to 1962, in eighteen areas that have remained substantially unchanged in respect of boundary and sources of water, are given in Table 11. These registrations, which are well distributed throughout the 36-year period, show consistently low sex ratios in all eighteen areas and a mean sex ratio of 100.6 : 100. The simple average sex ratio for Australia as a whole, for the years 1927 to 1963, is 105.3 : 100.

There are ninety-five local government areas in the agricultural region of south-west Western Australia. Published birth registrations for these areas are available from 1953 (*Statistical Registers for Western Australia*). These records show that forty-nine areas all have an excess of female births for the 10 years 1953 to 1962 (total registrations, 13,674 males and 13,907 females; sex ratio 98.3 : 100).

It is also relevant that annual birth registrations from 1911 consistently show that the rural areas of Australia have a lower sex ratio than the metropolitan areas. Roof water stored in tanks is the usual source of drinking water on farms throughout the country, and probably less than half the rural population has a water supply derived from surface catchment areas.

DISCUSSION

The observations for Perth (1941 to 1962), Adelaide (1911 to 1955) and Brisbane (1951 to 1962) give clear evidence of systematic seasonal variations in secondary sex ratio. These variations, though reasonably consistent between years within cities, do not fall in the same season in different cities. They do, however, become consistent between cities when considered in relation to seasonal variations in rainfall. In each city, a significantly greater proportion of males is found among newborn children conceived from about 6 to 10 weeks to about 18 to 20 weeks after the onset of the rainy season. The only serious exception occurs in Adelaide, where there is an additional significant increase in sex ratio for babies conceived in May, during the very beginning of the rainy season. No explanation can be given for this anomaly, but its existence should not be overlooked.

Seasonal changes in sex ratio were not, however, consistent in any of the three cities throughout the entire period for which records are available (1911 to 1962); but, in each city, the differences between groups of years were accompanied by changes in the management of the local water supply. In Adelaide, the seasonal changes largely disappeared after 1955, when the local catchment source of drinking water was first supplemented with water from the River Murray. In Perth, no seasonal variations were apparent before 1940, during the years when artesian sources of water were extensively used. In Brisbane, there is evidence of a fall in sex ratio for the years 1925 to 1952, when high levels of chlorination prevailed and may have led to changes in drinking habits.

The observations for Sydney, where rainfall is heavier and more evenly

distributed throughout the year than at Perth, Adelaide or Brisbane, show no marked seasonal pattern of sex ratio variation. However, months with greater than average rainfall tend to be followed 11 months later by months with higher than average sex ratios and years with greater than average rainfall tend to be followed by years of greater than average sex ratio. This reveals a similarity between Sydney and the other three cities.

These observations all suggest that there is a causal relationship between rainfall and sex ratio in areas of Australia with a local surface catchment source of drinking water. The turbidity of the water in the reservoirs varies markedly between wet seasons and dry seasons, and is highest during the first rains. It is suggested that some property of drinking water associated with this seasonal cycle influences sex ratio, and that the property most likely to be concerned is its content of trace elements. If this hypothesis is true, one would expect to find regional differences in sex ratio associated with differences in the chemical nature of soil and rock over which drinking water is collected and locally-produced food is grown. Records for the Tablelands of New South Wales and the agricultural region of south-west Western Australia, where certain trace element deficiencies are reported (McLachlan, 1955; Weir, Partridge & Fawcett, 1956; Spencer & Barrow, 1963; C.S.I.R.O., personal communications), do indeed suggest that unusually low sex ratios prevail in these areas.

The observations for Perth, Adelaide and Brisbane suggest that the rains first influence sex ratio in pregnancies conceived about 6 to 10 weeks after the onset of the rains. If the observed increases in sex ratio arise from increases in the relative viability of male embryos, the lag of 6 to 10 weeks is difficult to explain. If, however, they arise from an increase in primary sex ratio caused by an increase in the number or effectiveness of Y-spermatozoa, the lag period may be accounted for as the time required for the changes in spermatozoa to appear in the ejaculate.

According to Heller & Clermont (1963), the time elapsing between the production of a new stem-cell spermatogonium and the release of its descendant spermatozoa from the testis in man is a little more than 64 days. Probably a further 2 to 5 weeks are required for the spermatozoa to pass through the ductus epididymis to the ejaculate. This gives an estimated total of 11 to 14 weeks. Whilst events that differentially affect the numbers or properties of X- and Y-spermatozoa could occur during any part of this period, the most likely time is during the early post-meiotic stages of spermatogenesis, when the segregation of X- and Y-chromosomes is complete, the spermatids are undergoing extensive reorganization, and losses of cells appear to be considerable (see Bishop & Walton, 1960). This would be from about 24 days before release from the testis, or from about 5.5 to 8.5 weeks before arrival in the ejaculate. This estimate fits the observed lag period fairly well.

The suggested causal relationship between trace elements and sex ratio is, of course, far from proven, but it does provide a plausible explanation of the observations here reported. Perhaps it will be found to apply, through underlying dietary causes, to other instances of variation in sex ratio, such as those associated with social class, race and war. In any event, the hypothesis suggests lines for further analysis and experiment.

ADDENDUM

The rainfall for Sydney in 1962 was 44.90 in.; the sex ratio in 1963 was 104.94:100.

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