A FURTHER STUDY OF A-B-O BLOOD GROUPS AND DIFFERENTIAL FERTILITY AMONG WOMEN IN TWO AUSTRALIAN MATERNITY HOSPITALS

BY

R. L. KIRK AND J. W. SHIELD,

Department of Zoology, University of Western Australia,

N. S. STENHOUSE,

Division of Mathematical Statistics, Commonwealth Scientific and Industrial Research Organization,

LUCY M. BRYCE AND RACHEL JAKOBOWICZ

Australian Red Cross Blood Transfusion Service (Victorian Division) and the Queen Victoria Hospital, Melbourne

Two previous reports have examined certain aspects of the problem of incompatibility between mother and child with respect to the A-B-O blood groups for samples drawn from Australian Maternity hospitals. In the first of these, Bryce and others (1950) examined the mother-child blood-group combinations for 7,909 women confined in the Queen Victoria Hospital, Melbourne, during the years 1944-48. In certain mother-child combinations they observed striking differences from expectation. These differences were significant for the excess over expectation of group A infants born to group B mothers, and for the deficiency of group AB infants born to group A mothers. There was also a marked, but not significant, deficiency of group A infants to group O mothers. The analysis suggested also the possibility that AB women are more fertile than women belonging to other blood groups.

The second study, by Kirk and others (1953), examined the pregnancy experience of women of different blood groups confined in the King Edward Memorial Hospital, Perth, during the years 1948-51. A polynomial function fitted to the difference in the average number of pregnancies between women of group O and group A for each year of age from 16-40 showed a significant excess of pregnancies in group A women between the ages of 25 and 35, with a tendency for group O women to equal or surpass group A women over the age of 35. These authors suggested that the excess of pregnancies in group A women in the decade centred in age 30 might be due to the selective loss of children to group O women in incompatible mating groups, and that

group O women in compatible mating groups are more fertile, and their child-bearing activities more prolonged than those of group A women.

Since these reports were published, we have been able to add further material to both the Melbourne and Perth samples. These cities differ appreciably in size and social structure, and the reproductive patterns of the women in the two samples are significantly different. We thought it desirable therefore to analyse this extended material so that similarities and differences would be emphasized. Certain information was not always available for both samples for the whole of the period under study. In addition the heavy immigration of non-English people into Australia during the post-war years has introduced a heterogeneity into the samples for which due allowance must be made if errors in deduction are to be avoided. Despite these difficulties, however, the results recorded below indicate the value of this type of analysis in studying the effects of blood-group incompatibility on pregnancy experience.

METHODS

The source of the samples, and the techniques of collecting data and determining blood-groups have been given in detail by Bryce and others (1950) and Kirk and others (1953). In addition to the samples analysed in these two papers, 8,423 women were added to the Melbourne sample and 3,831 women added to the Perth sample during the years 1952 and 1953. The complete Melbourne sample therefore comprises 16,332 confinements for the years 1944-48 and 1952-53, the corresponding figure for the Perth sample being 9,952 confinements during the 6 years 1948-53.

RESULTS

(1) *Differences in Composition of Samples.*—The Melbourne 1944–48 and the Perth 1948–51 samples have been analysed in detail previously (Bryce and others, 1950; Kirk and others, 1953). No information was available for the earlier Melbourne sample with respect to mother's age or parity, and whether she was of English or non-English name. Tables I–III give the basic data for

the 1952 and 1953 sample for both Melbourne and Perth.

In both Melbourne and Perth samples there is a highly significant difference in the blood-group distributions for women of English and non-English name ($\chi^2 = 23.857$ and 26.081 respectively for 3 *d.f.*). There is no significant difference for the English name samples between Melbourne and Perth ($\chi^2 = 7.009$ 3 *d.f.*), or for the non-English name samples ($\chi^2 = 3.833$ 3 *d.f.*).

Although the blood-group frequencies for women of English name are not significantly different in the two samples, there is a significant difference in the age distribution of women entering the two hospitals (Table III, $\chi^2 = 33.878$ on 4 *d.f.*). The same is true also for women of non-English name ($\chi^2 = 23.316$ on 4 *d.f.*). For the English name sample the difference is due largely to the increased number of young mothers in Perth. The women of non-English name are significantly older in the two samples than those of English name. This is readily understood, since many of them are recent immigrants to Australia and their reproductive experience has been more seriously interfered with by war and its aftermath than is the case for the women of English name. Most of the latter have been resident in Australia since birth. (The validity of this statement has been

TABLE I
COMPOSITION OF THE 1952–53 SAMPLES FOR MELBOURNE AND PERTH

Blood Group of Mother	Melbourne			Total	Perth			Total
	Single Births	Twin Births	Rank and Age not Stated		Single Births	Twin Births	Rank and Age not Stated	
O	3,741	54	118	3,913	1,780	20	—	1,800
A	3,202	31	102	3,335	1,505	18	—	1,523
B	801	11	38	850	396	6	—	402
AB	306	4	15	325	104	2	—	106
All Groups	8,050	100	273*	8,423	3,785	46	—	3,831

* Five of these cases had no age stated, but pregnancy rank was recorded. They have been included in the single birth analysis by rank.

TABLE II
DISTRIBUTION OF ABO BLOOD GROUPS AMONG MOTHERS OF ENGLISH AND NON-ENGLISH NAME IN TWO AUSTRALIAN MATERNITY HOSPITAL SAMPLES

Blood Group	Melbourne, 1952 and 1953						Perth, 1952 and 1953					
	English Name		Non-English Name		Total Sample		English Name		Non-English Name		Total Sample	
	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.
O	3,196	47.22	599	43.37	3,795	46.56	1,384	48.17	416	43.42	1,800	46.99
A	2,697	39.84	536	38.81	3,233	39.67	1,153	40.13	370	38.62	1,523	39.75
B	632	9.34	180	13.04	812	9.96	262	9.12	140	14.61	402	10.49
AB	244	3.60	66	4.78	310	3.80	74	2.58	32	3.34	106	2.77
All Groups	6,769	100.00	1,381	100.00	8,150	99.99	2,873	100.00	958	99.99	3,831	100.00

TABLE III
AGE DISTRIBUTION OF MOTHERS OF ENGLISH AND NON-ENGLISH NAME IN TWO AUSTRALIAN MATERNITY HOSPITAL SAMPLES

Age Group (yrs)	Melbourne, 1952 and 1953						Perth, 1952 and 1953					
	English Name		Non-English Name		Total Sample		English Name		Non-English Name		Total Sample	
	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.
20 and under	1,094	16.16	158	11.44	1,252	15.36	581	20.22	112	11.69	693	18.09
21–25 ..	2,492	36.81	488	35.34	2,980	36.56	1,043	36.30	279	29.12	1,322	34.51
26–30 ..	1,780	26.30	454	32.87	2,234	27.41	666	23.18	314	32.78	980	25.58
31–35 ..	919	13.58	200	14.48	1,119	13.73	346	12.04	152	15.87	498	13.00
36 and over	484	7.15	81	5.87	565	6.93	237	8.25	101	10.54	338	8.82
All Ages ..	6,769	100.00	1,381	100.00	8,150	99.99	2,873	99.99	958	100.00	3,831	100.00

checked for a single year in the Perth sample by examining the information recorded on the birth certificates of all babies born in the King Edward Memorial Hospital during 1952*).

Because of the difference in age structure between the two samples we have considered it important to analyse the data from Melbourne and Perth separately.

(2) *Mean Number of Pregnancies per Woman.*—It has been possible to calculate the mean number of pregnancies for women of English name in the Melbourne sample for 1952 and 1953 and in the Perth sample for the whole period 1948–53 (Table IV). In both places women of group A have experienced more pregnancies on the average than group O women. In the Melbourne sample the difference of 0.055 pregnancies per woman is not significant ($t = 1.271$) but the difference in Perth of 0.103 pregnancies per woman is significant at the 5 per cent. level ($t = 2.296$).

TABLE IV
MEAN NUMBER OF PREGNANCIES PER WOMAN IN EACH
BLOOD GROUP
(Women of English Name only)

Blood Group	Melbourne, 1952 and 1953			Perth, 1948 to 1953		
	No. of Women	Mean No. of Pregnancies	S.D. of Mean	No. of Women	Mean No. of Pregnancies	S.D. of Mean
O	3,196	2.503	0.029	3,711	2.702	0.030
A	2,697	2.558	0.033	3,281	2.805	0.033
B	632	2.429	0.062	755	2.767	0.069
AB	244	2.508	0.108	205	2.756	0.126
All Groups	6,769	2.518	0.020	7,952	2.752	0.021

It is of interest to note that the mean number of pregnancies for AB women in these two samples is lower than group A in one and than both group A and group B in the other. These figures do not lend support therefore to our earlier suggestion (Bryce and others, 1950) that AB women might be more fertile than women in other blood groups.

(3) *Mean Number of Pregnancies for Group O and A Women at Different Ages.*—In Table V (opposite) the mean number of pregnancies for group O and A women is given for age from 16–40 yrs. If the difference between the means for group O and group A women is plotted, it is possible to fit a curve to the values obtained. For the Perth sample

the difference tends to increase linearly with age, and in the fitted curve the linear term accounts for the bulk of the variation. Unlike the earlier and smaller Perth sample, there is no longer any apparent tendency for group O women to compensate over the age of 35 for the clear-cut deficiency in pregnancy experience of group O women between the ages of 25–35. We can conclude, therefore, that in the Perth 1948–53 sample, women of group A have experienced relatively more pregnancies than group O women: not only is the difference in the means significant, but the difference increases linearly with age.

A similar analysis applied to the difference in mean number of pregnancies experienced by women of English name of groups A and O in the Melbourne 1942–53 sample shows no consistent trend, only the quintic term in the polynomial having any significance. At first this result seems surprising, since the Perth and Melbourne samples are approximately the same size. A more detailed examination of the data in Table V reveals that a trend similar to that present in the Perth sample is present in the earlier age groups, but the variation from year to year above age 35 becomes very great in the Melbourne sample. In fact the polynomial fitted to the differences between group A and group O women from age 16 to 33 reveals a significant trend, the linear and quadratic terms accounting for the bulk of the variation. It should be pointed out clearly, however, that even though the trend in pregnancy experience in the younger age groups is the same in both the Melbourne and Perth samples, the difference between group A and group O women in Melbourne is never as large as is the case in Perth.

It seems likely that the discrepancy between the analysis for the Perth and Melbourne samples is related to the difference in the overall pregnancy experience of women in the two samples. The Perth women of English name have had 0.23 more pregnancies per woman than the corresponding women in Melbourne, the difference being highly significant ($t = 7.97$, $P < 0.001$). The difference in pregnancy experience between group O and group A women will almost certainly be less marked in the sample with the smaller average number of pregnancies per woman. The importance of bearing in mind the difference in pregnancy experience when comparing the relationship of blood groups to fertility in samples from different places will be discussed more fully in a later section.

(4) *Mother-Child Blood-Group Combinations.*—For the Melbourne sample the blood-group of the child has been determined in addition to that of the

* We are indebted to the Registrar-General for Western Australia for permission to search his records.

TABLE V

MEAN NUMBER OF PREGNANCIES TO GROUP O AND A WOMEN OF ENGLISH NAME ONLY AT DIFFERENT AGES
(Melbourne, 1952 and 1953; Perth 1948 to 1953)

Age of Mother (yrs)	Melbourne, 1952 and 1953						Perth, 1948 to 1953					
	Group O Rh + and -			Group A Rh + and -			Group O Rh + and -			Group A Rh + and -		
	No. of Women	No. of Pregnancies	Mean No. of Pregnancies	No. of Women	No. of Pregnancies	Mean No. of Pregnancies	No. of Women	No. of Pregnancies	Mean No. of Pregnancies	No. of Women	No. of Pregnancies	Mean No. of Pregnancies
16 or less ..	23	23	1.0000	25	26	1.0400	33	37	1.1212	18	18	1.0000
17	70	77	1.1000	33	37	1.1213	79	90	1.1392	73	77	1.0548
18	97	118	1.2165	78	94	1.2051	152	187	1.2303	137	164	1.1971
19	143	204	1.4266	138	195	1.4130	233	319	1.3691	202	281	1.3911
20	197	304	1.5431	151	235	1.5563	282	434	1.5390	255	409	1.6039
20 and under	530	726	1.3698	425	587	1.3812	779	1,067	1.3697	685	949	1.3854
21	232	396	1.7069	194	329	1.6959	289	512	1.7716	247	465	1.8826
22	232	439	1.8922	202	394	1.9505	288	551	1.9132	247	490	1.9838
23	236	454	1.9237	198	407	2.0556	260	576	2.2154	245	518	2.1143
24	247	516	2.0891	199	444	2.2312	269	629	2.3383	221	543	2.4570
25	213	486	2.2817	207	481	2.3237	232	588	2.5345	206	514	2.4951
21-25 ..	1,160	2,291	1.9750	1,000	2,055	2.0550	1,338	2,856	2.1345	1,166	2,530	2.1698
26	219	540	2.4658	199	519	2.6080	219	597	2.7260	169	475	2.8107
27	191	504	2.6387	151	388	2.5695	200	595	2.9750	172	518	3.0116
28	152	465	3.0592	127	386	3.0394	163	537	3.2945	148	498	3.3649
29	138	404	2.9275	112	344	3.0714	144	465	3.2292	137	518	3.7810
30	133	440	3.3083	117	366	3.1282	113	399	3.5310	126	511	4.0556
26-30 ..	833	2,353	2.8247	706	2,003	2.8371	839	2,593	3.0906	752	2,520	3.3511
31	110	383	3.4818	97	325	3.3505	106	422	3.9811	105	413	3.9333
32	114	415	3.6404	93	306	3.2903	104	381	3.6635	108	432	4.0000
33	76	279	3.6711	69	247	3.5797	79	328	4.1519	72	307	4.2639
34	72	266	3.6944	56	220	3.9286	64	260	4.0625	65	312	4.8000
35	66	242	3.6667	47	167	3.5532	63	292	4.6349	60	271	4.5167
31-35 ..	438	1,585	3.6187	362	1,265	3.4945	416	1,683	4.0457	410	1,735	4.2317
36	61	252	4.1311	43	169	3.9302	74	347	4.6892	53	269	5.0755
37	44	183	4.1591	42	198	4.7143	51	263	5.1569	59	305	5.1695
38	41	157	3.8293	37	172	4.6487	56	275	4.9107	53	273	5.1509
39	36	182	5.0556	15	58	3.8667	42	235	5.5952	30	180	6.0000
40 and over	53	277	5.2264	67	396	5.9104	116	711	6.1293	73	438	6.0000
36 and over	235	1,051	4.4723	204	993	4.8676	339	1,831	5.4012	268	1,465	5.4664
All Ages ..	3,196	8,006	2.5050	2,697	6,903	2.5595	3,711	10,030	2.7028	3,281	9,199	2.8037

mother, and we have been able to construct a Table showing the A-B-O mother-child combinations for 16,179 single births which occurred to women of English and non-English name during the period

1944-48 and 1952-53 (Table VI). The expected number of children for each combination was calculated by assuming that the mothers were mated at random with a sample of fathers having the same

TABLE VI

MOTHER-CHILD COMBINATIONS IN MELBOURNE SAMPLE 1944-48 + 1952-53. (SINGLE BIRTHS ONLY)

Blood Group of Children			Blood Group of Mothers				
			O	A	B	AB	All Groups
No. of Children	O (observed)		5,334	1,879	539		7,752
	(estimated)		(5,172.32)	(1,862.30)	(529.77)		(7,564.39)
	A (observed)		1,754	4,124	218	273	6,369
	(estimated)		(1,862.30)	(4,115.30)	(190.75)	(259.42)	(6,427.77)
	B (observed)		497	218	681	226	1,622
	(estimated)		(529.77)	(190.75)	(698.11)	(210.28)	(1,628.92)
	AB (observed)			185	167	84	436
	(estimated)			(259.42)	(210.28)	(88.22)	(557.92)
All Groups			(observed)	7,585	6,406	1,605	16,179
			(estimated)	(7,564.39)	(6,427.77)	(557.92)	(16,178.99)

blood-group distribution as the mothers. In the absence of information on the real blood-group distribution of the fathers this assumption seems to be the most reasonable one to adopt.

There is a theoretical objection to this pooling of the results for the English and non-English name samples. The expectations calculated by using the gene frequencies from the total sample will be different from the expectations derived from the gene frequencies of the English and non-English name groups treated as separate isolates. We have carried out the calculations for the 1952 and 1953 sample by using both the gene frequencies calculated separately for the women of English and non-English name and gene frequencies based on the pooled sample. The difference between the expected numbers obtained by these two methods is approximately 0.1 per cent. We consider, therefore, that the errors introduced by using gene frequencies based on the total sample for 1944-48 and 1952-53 will be rather less than 0.1 per cent., if the other assumption on the gene frequency of the fathers is valid. The gene frequencies have been calculated by the method of maximum likelihood (Stevens, 1938), and the values finally used were $p = 0.246,193$, $q = 0.070,035$, and $r = 0.683,772$.

A comparison of the observed and expected values reveals discrepancies of the kind noted in our earlier paper (Bryce and others, 1950). The χ^2 values for each compartment of Table VI are given in Table VII. From this it will be seen that there are significant deficiencies of group A children to group O mothers, and of group AB children to both group A and B mothers. There are also significant excesses of group O children to group O mothers, of group B children to group A mothers, and of group A children to group B mothers. The direct evaluation of the mother-infant blood-group relationship of all 16,179 cases examined also reveals a highly significant difference ($\chi^2 = 23.22$; $P < 0.001$).

TABLE VII
 χ^2 FOR DIFFERENCES BETWEEN OBSERVED AND CALCULATED VALUES IN TABLE VI

Blood Group of Children	Blood Group of Mothers				All Groups
	O	A	B	AB	
O	+2.248	+0.387	+0.401		+2.157
A	-2.510	+0.136	+1.973	+0.843	-0.733
B	-1.424	+1.973	-0.648	+1.084	-0.171
AB		-4.621	-2.985	-0.450	-5.162

If the discrepancies noted above are due to the selective action of immune antibodies reacting with foetal tissues we might expect the distribution of

mother-child combinations to be different for first-born, second-born, third-born children, etc. This can be investigated for single births in the Melbourne 1952-53 sample. If the number of group A and B children to group O mothers is compared with the group O children to group A and B mothers respectively (Table VIII), it will be seen that there is no deficiency in the former case for first-born children. There is, however, a marked deficiency for second- and third-born group A and B children to group O mothers when compared with second- and third-born group O children to group A and B mothers, though the difference disappears again for the fourth and higher-born children. The expected number of each birth rank has been calculated using the gene frequencies based on the total mother sample. A comparison of the observed and expected values for each birth rank in each mother-child combination confirms the conclusions reached above which were based on direct comparisons within the body of the Table.

TABLE VIII
MOTHER-CHILD COMBINATIONS BY BIRTH RANK IN MELBOURNE SAMPLE 1952-53
(Single Births only)

Blood Group of Children	Birth Rank	Blood Group of Mothers				
		O	A	B	AB	All Groups
O	1 ..	881	287	81		1,249
	2 ..	754	272	90		1,116
	3 ..	475	187	52		714
	4 ..	269	92	17		378
	5 and over	278	106	23		407
A	1 ..	287	649	40	53	1,029
	2 ..	236	615	27	32	910
	3 ..	146	389	12	23	570
	4 ..	92	196	11	17	316
	5 and over	93	217	11	16	337
B	1 ..	79	32	109	34	254
	2 ..	78	33	112	48	271
	3 ..	33	17	65	23	138
	4 ..	15	11	32	14	72
	5 and over	26	11	38	11	86
AB	1 ..		28	22	19	69
	2 ..		34	28	7	69
	3 ..		12	13	7	32
	4 ..		5	11	2	18
	5 and over		10	9	1	20
All Groups	1 ..	1,247	996	252	106	2,601
	2 ..	1,068	954	257	87	2,366
	3 ..	654	605	142	53	1,454
	4 ..	376	304	71	33	784
	5 and over	397	344	81	28	850
All Ranks		3,742	3,203	803	307	8,055

These results would suggest that the observed deficiency of group A and B children to group O mothers might well be due to the operation of an immune response mechanism. On the other hand it is interesting to note that the marked deficiency of group AB infants to both group A mothers and

group B mothers is present for first-born children as well as for those of higher rank. Similarly the observed excess of group B children to group A mothers and group A children to group B mothers shows no relationship to birth rank. A larger sample would need to be analysed for any significance to be attached to the discrepancies noted in these latter cases.

DISCUSSION

The present study of two large samples of mothers from Australian maternity hospitals is of interest for the current discussion of selective action within the ABO blood-group system. This problem has been reviewed recently by Neel (1954) and it is clear that even though nearly 30 years have elapsed since Hirsfeld and Zborowski (1925) first noted the deficiency of group A children in families where the mother is group O and the father group A there has still been no satisfactory assessment of all the evidence now available.

Levine (1943) collected evidence which supported Hirsfeld's original view that matings $A \delta \times O \phi$ produced fewer offspring than reciprocal matings $O \delta$ and $A \phi$. Waterhouse and Hogben (1947) in a more detailed study of the same problem arrived at similar conclusions for their $A \times O$ matings, though the $B \times O$ matings showed a discrepancy opposite to that which would be expected on the basis of selection in incompatible mating groups.

Waterhouse and Hogben's work has been criticized recently by Bennett and Brandt (1954). This criticism rests in part on the heterogeneity of families segregating for group A and O children in the twelve samples included in their survey. Waterhouse and Hogben drew on family studies of ABO blood-groups carried out in a number of different countries. Matsunaga (1953) has now made a similar study based solely on Japanese material and finds a significant deficiency of children in matings $A \delta \times O \phi$ and $B \delta \times O \phi$. In a further study of two mining communities in Hokkaido, Matsunaga and Itoh (1954) have demonstrated a highly significant reduction in the number of living children for women in A-B-O incompatible mating groups compared with those in compatible mating groups.

A different approach was made to the problem by Boorman (1950) and by Bryce and others (1950). If group A or B children are being selectively eliminated by group O mothers, the mother-child combinations for large unselected samples of mothers having babies should reveal deviations from expectation. In both these studies there was no significant deficiency of group A or B children born to group O mothers, though in the much larger

Australian sample studied by Bryce and others (1950) a marked deficiency was found in group A children to O mothers. These authors draw attention in their work, however, to much bigger discrepancies, which are present also in Boorman's study, principally the deficiency of group AB children to A and B mothers, and the excess over expectation of group B children to group A mothers and group A children to group B mothers. These two latter discrepancies are difficult to reconcile with the concept of foetal loss through selection in incompatible matings, since both A mother-B child and B mother-A child are incompatible. A somewhat similar study by Johnstone (1954) of an English maternity hospital sample included the blood groups of the fathers as well as of the mothers and children. He found no deficiency of group A children in matings $A \delta \times O \phi$ and points out that if the expectations are distributed in the usual way there is in fact a significant deficiency of group O children in matings $O \delta \times A \phi$. This discrepancy, too, is difficult to reconcile with incompatible selection as ordinarily defined, nor are we yet aware of any clinical or serological evidence which could account for the magnitude of the selective effect stated for the loss of group O children to group A mothers.

Data based on maternity hospital samples of the kind published by Boorman (1950) and Johnstone (1954) must be interpreted with caution when use is made of them for comparison with studies such as those of Waterhouse and Hogben, and Matsunaga. In these latter investigations the material was collected in the main for studies of inheritance of particular genes, so that the proportion of one-child families was low. In both Boorman's and Johnstone's samples, however, the mean number of pregnancies per woman was less than two, approximately 50 per cent. of the mothers being primiparae. If selective action within the ABO blood groups is in any way comparable to that in the Rh system, very much larger samples than those presented by Boorman and Johnstone would be required to manifest the effects they were looking for if the majority of the women in the sample are experiencing only their first or second pregnancy.

Indeed such information relevant to the question of the influence of incompatibility on pregnancy experience as can be extracted from their published data suggests that selective action is occurring in higher birth-ranks. In Boorman's data the mothers who are classed as incompatible for the A antigen suffer a marked deficiency in their pregnancy experience above the age of 20 compared with compatible mothers, the difference increasing with age. At age 40-49 the figures are 2.91 and 3.86.

Similarly an examination of Table VIa of Johnstone's paper reveals a significant deficiency of mothers experiencing their fourth or higher pregnancy in the mating group $A \text{ ♂} \times O \text{ ♀}$ compared with $O \text{ ♂} \times A \text{ ♀}$ (for the whole table $\chi^2 = 10.392$; $4.d.f.$; $0.05 > P > 0.02$).

Our own studies of two Australian maternity hospital samples emphasize the necessity for caution in interpreting samples of this kind. Drawn from two separate populations, the Perth and Melbourne samples are significantly different from one another in age structure and overall pregnancy experience per woman. Using a simple name analysis, both samples can be broken up into an English and non-English name group, there being a highly significant difference in blood-group frequency between the English and non-English name groups for both places. It is possible that the use of more refined techniques could split each of these samples into a still larger number of groups of more homogeneous composition.

A comparison of the English name groups in each sample brings out the following points. Group A women in both samples have experienced slightly more pregnancies than have group O women. The difference is significant for the Perth sample but not so for Melbourne. A more detailed study of the difference in pregnancy experience by each year of age for group O and A women suggests, however, that the tendency for group A women to experience an increasingly large number of pregnancies with increasing age as compared with group O women is true in Melbourne as well as in Perth. That the differences are much smaller in the Melbourne sample is undoubtedly due to the highly significant difference in pregnancy experience of the women in the two samples.

A comparison of the expected and observed number of children in various mother-child combinations for ABO blood groups reveals a number of significant discrepancies. The highly significant deficiencies of group A children to group O mothers and of group AB children to group A and B mothers supports the hypothesis that mother-child incompatibility is eliminating a proportion of the incompatible children. This simple explanation, however, cannot account for the observed excess of group B children to group A mothers and of group A children to group B mothers. These latter discrepancies still await a satisfactory explanation.

A study of mother-child combinations by birth rank for the Melbourne sample shows no deficiency of group A or B children born to group O mothers in the first birth rank, but a marked deficiency in the second, and an even greater deficiency in the third.

This study lends support to the concept that a proportion of women of blood group O progressively suffer a reduction in fertility due to the operation of selection in incompatible pregnancies. Many of the other possibilities related to the general problem of blood group polymorphism in man must await the accumulation of still larger samples before answers approaching the decisive can be given to the questions raised.

SUMMARY

(1) Two Australian maternity hospital samples have been analysed to throw light on the problem of incompatibility between mother and child within the ABO blood-group system. The first sample comprised mothers entering the Queen Victoria Hospital, Melbourne, during the years 1944-48 and 1952-53. The other sample comprised mothers entering the King Edward VII Maternity Hospital, Perth, during the years 1948-53.

(2) The Melbourne and Perth samples revealed highly significant differences in blood-group distribution between women of English and non-English name, but there were no significant differences in blood-group distribution between the Melbourne and Perth samples for women of English name, or for women of non-English name compared separately. Melbourne and Perth did differ significantly, however, in the age composition and in the overall pregnancy experience of all women in the samples.

(3) In both Melbourne and Perth group A women had a higher average number of pregnancies than group O women. The difference was significant for Perth but not for Melbourne. The curve fitted to the difference in mean number of pregnancies between the two groups of women for each year of age from 16-40 showed a significant linear increase in the difference group A — group O for Perth. The same trend was present for the Melbourne sample below age 35, but the greater variability in this sample above that age reduced the significance of the trend over the entire age range studied. The discrepancy between the two samples is due probably to the smaller average number of pregnancies of women in the Melbourne sample.

(4) A comparison of the calculated and observed number of children in different mother-child blood-group combinations for 16,179 single births in Melbourne reveals a significant deficiency of group A children to group O mothers and group AB children to group A and B mothers, and a significant excess

of group O children to group O mothers, of group A children to group B mothers, and group B children to group A mothers.

(5) A breakdown of mother-child blood-group combinations by birth rank reveals that the deficiency of group A and B children to group O mothers is absent for first-born children, present for second-born children, and greatest for third-born children.

(6) These results are discussed in relation to other work of a similar kind, and it is suggested that the results presented support the hypothesis that incompatibility between mother and child in the ABO blood-group system results in selective loss of a proportion of incompatible children.

We should like to thank the medical and nursing staff of the Queen Victoria Hospital for their ready co-operation. We are indebted also to the Medical Superintendent, Dr. A. G. Mathew, and Matron Walsh of the King Edward Memorial Hospital, Perth, for giving us access to their records, to Mrs. B. M. Shield for clerical assistance, and to the Research Grants Committee of the University of Western Australia for financial support.

REFERENCES

- Bennett, J. H., and Brandt, J. (1954). *Ann. Eugen., Camb.*, **18**, 302.
 Boorman, K. E. (1950). *Ibid.*, **15**, 120.
 Bryce, L. M., Jakobowicz, R., McArthur, N., and Penrose, L. S. (1950). *Ibid.*, **15**, 271.
 Hirszfeld, L., and Zborowski, M. (1925). *Klin. Wschr.*, **1**, 1152.
 Johnstone, J. M. (1954). *British Journal of Preventive and Social Medicine*, **8**, 117.
 Kirk, R. L., Kirk, M., and Stenhouse, N. S. (1953). *Ibid.*, **7**, 1.
 Levine, P. (1943). *J. Hered.*, **34**, 71.
 Matsunaga, E. (1953). *Proc. imp. Acad., Japan*, **29**, 399.
 — and Itoh, S. (1954). *Ibid.*, **30**, 677.
 Neel, J. V. (1954). *Amer. J. hum. Genet.*, **6**, 208.
 Stevens, W. L. (1938). *Ann. Eugen., Camb.*, **8**, 362.
 Waterhouse, J. A. H., and Hogben, L. (1947). *British Journal of Social Medicine*, **1**, 1.

pressure 10 g./mm.² for boys and girls from age 2 years upwards are given for biceps, triceps, sub-scapular, sub-costal, supra-iliac and abdominal regions. Standard errors at the different ages are also included.

(5) The caliper measurements have been transformed into equivalent actual fat thickness as measured from x-ray photographs.

(6) Mean measurements for different nutritional and social groups descend from good to poor nutrition and from high to low social class, but the highest groups in both cases show little difference from the age standards.

(7) The frequency distribution of subcutaneous fat measurements is positively skewed, and it is suggested that this may be partly due to the inclusion of a condition of obesity acting as a separate entity. Research is needed to differentiate over-fat or over-thin children on clinical grounds of health and optimal functioning.

(8) Methods of estimating the total quantity of subcutaneous fat in the body from measurements of surface area and a representative set of caliper measurements are being studied.

I should like to express my indebtedness to Drs. W. T. C. Berry and P. J. Cowin for permission to include many of their measurements of body fat in the Table of Norms. I am also most grateful to Dr. J. M. Tanner and Mr. R. Whitehouse for making available the extensive series of comparisons between caliper and x-ray measurements obtained during the Harpenden Growth Study from which I calculated the regression equation. Dr. D. A. W. Edwards has also very kindly allowed me to make use of his data on fat measurements in women. From these the National Physical Laboratories calculated the Tables of Correlations which I have analysed. I should also like to acknowledge the help given by Dr. E. R. Bransby in organizing the field trials, and for helpful criticism throughout the investigation.

REFERENCES

- Adcock, E. W., Hammond, W. H., and Magee, H. E. (1947). *J. Hyg.*, 45, 65.
 Berry, W. T. C. (1951). *Monthly Bull. Min. Hlth. Lab. Serv.*, 10, 155.
 — and Cowin, P. J. (1951). *Med. Offr.*, 85, 213.
 — (1954). *Brit. J. Nutrit.*, 8, 79.
 Brozek, J., and Keys, A. (1951). *Ibid.*, 5, 194.
 Draper, G. (1924). "Human Constitution: a Consideration of its Relationship to Disease", p. 209 et seq. Saunders, Philadelphia.
 Du Bois, E. F. (1936). "Basal Metabolism in Health and Disease", 3rd ed., p. 129. Lea and Febiger, Philadelphia.
 Edwards, D. A. W. (1950). *Clin. Sci.*, 9, 259.
 — (1955). *Voeding*, 16, 57.
 —, Hammond, W. H., Healy, M. J. R., Tanner, J. M., and Whitehouse, R. H. (1955). *Brit. J. Nutrit.*, 9, 133.
 Freeman, W. (1934). *Ann. intern. Med.*, 7, 805.
 Hammond, W. H. (1953a). *Hum. Biol.*, 25, 65.
 — (1953b). *British Journal of Preventive and Social Medicine*, 7, 231.
 Tanner, J. M. (1955). "Growth at Adolescence". Blackwell, Oxford.

APPENDIX

MEASURING SITES

Forearm: Lateral surface half-way along.

Forearm: Proximal surface half-way along.

Biceps: Median line over middle of biceps.

Upper Arm: Lateral, midway between acromial edge and olecron.

Triceps: Half-way down the back of the arm over the triceps.

Triceps: Top of triceps.

Sub-scapular: Immediately below inferior angle of scapula following the natural fold at an angle approximately 45° to the vertical.

Inter-scapular: Between lowest points of scapulae.

Supra-iliac: Immediately above the left iliac crest.

Sub-costal: Immediately under the costal margin vertically below the nipple.

Abdominal: About 1 inch to left of and below umbilicus.

Lower Leg: Lateral, below head of tibia.

Under Chin:

Thigh: Median line 2 in. above patella.

Thigh: Mid-thigh lateral.

Pectoral: Below clavicle in nipple line.

CORRIGENDUM

In an article by Kirk, Shield, Stenhouse, Bryce and Jakobowicz, *Brit. J. prev. soc. Med.* (1955), 9, 104, in the heading of Table VII on p. 108 for χ^2 , read χ .