AN INVESTIGATION OF THE GENETIC STRUCTURE OF SOCIAL CLASS

Penelope Elspeth Jane Wheatcroft

A thesis submitted for the degree of
Doctor of Philosophy in October 1971

AN INVESTIGATION OF THE GENETIC STRUCTURE OF SOCIAL CLASS

Summary

The aim of the present survey was to test the hypothesis that genetic differences between the social class groups in Britain exist and can be demonstrated at the population survey level.

It was decided to undertake a survey of a wide range of inherited characteristics of high heritability such as eye colour and PTC tasting with the object of comparing the frequencies of these variables in different social class groups.

The original intention was to use an adult sample of subjects in order to obtain a direct social class grouping. This proved impossible, and it was necessary to substitute a sample of schoolchildren. As a consequence it was only possible to use parental occupation and type of school attended as indications of the social class of the subjects.

Various methods of determining the survey variables were investigated, and the survey data was handled by use of a computer. The program for this was written as a part of the project.

The survey results showed that the social class groups differed significantly for a number of variables. There were also significant differences between the school types. Several of the characteristics studied showed significant sex differences, and

some traits were significantly associated with the regional origins of the subject.

In addition to these significant associations it was found that many pairs of characteristics were significantly associated. It was also possible to provide basic population frequency data for the traits used.

A limited twin survey provided estimates of the heritability of the traits under study. Such data was not previously available for many of the traits.

The implications of the survey results were discussed with reference to previous studies in the field of human genetic polymorphism.

'There's no art
To find the mind's construction in the face;'

<u>Macbeth</u>

William Shakespeare.

INDEX

Page

Page

Page

Page

Page

Page

Page

Page

Page

Page

Page

List of figures in text

ACKNOWLEDGEMENTS

Thanks are due to all those mentioned in this account, who gave invaluable advice and assistance.

Particular gratitude is due to the many survey subjects, who were willing to take part in the investigation eagerness and interest, and to the staffs of the school visited whose cooperation made this survey possible.

1 INTRODUCTION

1A Background and Previous Work

If a biologist of an alien life form were to study the ecology of the human species he would be interested to note the phenomenon of sympatric and apparently identical population groups which show limited interbreeding. Further investigation would show that these groups were formed on the basis of non-biological factors, such as status within the human community and religion. He might then be tempted to propose the existence of environmental varieties of man, though the fertile unions between members of different groups would show him that the differentiation was still at an early level. A logical procedure for the alien would then be to collect and examine specimens of the various groups in order to determine whether any physical differences could be detected.

The present project attempts to analyse the relationships between the partially segregated groups in the British class structure from this point of view. The hypothesis to be tested is that the various social class levels represent different environmental niches, and that the groups occupying these niches will show some genetic differences. Whether these differences would be detectable by the available methods of population study was a point which could not be decided in abstract. However examination of the relevant literature gave some support for the undertaking. During the preparation of of this work over 600 research papers were consulted, and though studies of social variables in conjunction with physical characteristics formed only a small proportion of this total, it was found that the majority of those concerned with this topic were able to report positive results.

It might be argued that population differences, if present, would be so slight as to be undetectable, but it has been shown that spacially separate human populations tend to differ in their frequencies of marker genes. For example, it is possible to draw clines of gene frequencies across the map of Europe and the world, representing such variables as mid-digital hair and the ABO blood group system (Brothwell & Molleson 1965, Mourant et al, 1958). Even within the area of the British Isles it is possible to demonstrate regional differences in inherited characteristics, Roberts (1942) found a difference in blood group frequencies between North and South Wales, and Morgan Watkins found that the two frequencies differed on the two sides of Offa's dyke. Lee (1957) has noted that there are regional differences in intelligence in Britain, while Ashley (1968, 1969 abc) has noted a raised incidence of certain diseases in Wales. Sunderland (1955) found regional differences in hair pigmentation, and has also demonstrated differences in PTC sensitivity within a single county (1966).

Regional variation in Britain may represent basic differences in the anthropological origins of the various areas of the country and so it is of doubtful value in supporting the present hypothesis. But purely social factors such as religion have been shown to act as an effective bar to interbreeding between two groups. The Japanese island of Kuroshima has a total population of only approximately 2,300; yet this total is divided into two groups, the Buddhists and the Roman Catholics, and Schull and co-workers (1962) showed the groups differed in various characteristics. In America Glass has noted that religious isolates showed different gene frequencies from the general population (1952, Glass et al 1956). It would be valuable in this context to examine the frequencies of genetic markers in the Protestant and Catholic factions of Ulster and Eire, though once again the aspect of colonization could confuse the results.

However the major divisive factor in present Western society is that of social class success. There has been a change in attitude since Parsons (1920) was able to talk of the upper and lower classes without need of further definition, but many class distinctions still remain. Lipset and Bendix (1960) noted that social class could be definied as 'strata of society composed of individuals who accept each other as status equals, and are hence qualified for intimate association.'

This is not to underestimate the considerable degree of social mobility which acts to maintain the proportional stability of the various social levels. Young and Gibson (1963) have noted that those sons who are more intelligent than their fathers tend to move up the social scale relative to their parent, while the less intelligent sons move down. Such intergenerational mobility is a feature of most industrial societies, with the level of upward mobility balancing that of downward mobility (Miller 1960, Burt 1961).

Social mobility may not necessarily mean a change in the social class attitudes of the mobile person. Goldthorpe and co-workers (1967) noted that 'the acquisition by manual workers of relatively high incomes and living standard does not lead to widespread changes in the direction of middleclassness.' Mao Tse-Tung (1966) has suggested that in a class society 'every kind of thinking..... is stamped with the brand of a class.' If these views are correct it would be expected that a proportion at least of the socially mobile would remain separated from their new group by retaining the previous habits. Goldthorpe and Lockwood (1964) found that affluent workers are not accepted into the white-collar class.

If the social class groups are to be considered as distinct population groups showing limited interbreeding, then it must be expected that differences in gene frequencies will occur. Fisher (1958) has suggested that social classes tend to become differentiated 'like local varieties of species.' He proposes that this process is not controlled by natural selection but rather by the factors controlling social mobility. Burt (1959) proposed that the formation of societies where interfertile classes worked together but did not breed together may have been responsible for the advancement of many societies. Such a situation allows for the segregation of individuals of above average ability.

Social class may be taken as a crude rating of success in the present competitive society. Though social class is not a direct measurement of intelligence, there is a strong association between these two factors. As previously mentioned changes in intelligence levels of offsprings relative to their parents tend to lead to social class mobility. Thus it is possible to interpret the effect of social mobility as sorting the different intelligence levels within each generation to maintain an equilibrium position within the class groups.

Intelligence is not wholly determined by heredity, though there is a very large genetic component involved. It is therefore of interest that marked differences in intelligence levels are found between the various social classes. Conway (1958) suggested that multifactorial inheritance of intelligence acting with social mobility would explain the situation. Burt (1959) concluded that 'there must now be appreciable differences in the genetic constitution of different social classes.' He suggests that these differences will be manifest as variations in the mean intelligence level from class to class. Burt suggests that class differences have been present in this country since before the Anglo-Saxon and Norman Conquests, though the rigidity of the class barriers is now relaxing.

A further factor tending to segregate different levels of intelligence is that of assortative mating. It is found that there is a significant tendency for couples to marry assortatively with regard to IQ, social class background and education (Garrison et al 1969). The effect of such assortation would be to increase the rate of selection in both directions from the median level of ability. Assortative mating for any of the above traits will therefore tend to perpetuate class differences.

Various studies have shown that major disabilities, such as schizophrenia and chronic bronchitis are associated with lower social class, but this may be due to the effect of the condition on the patient. However Meadows (1961) showed that those patients who suffered from chronic bronchitis tended to show downward social mobility even before the full effects of the disease. In the case of schizophrenia an excess of cases were noted in SC IV and V by Hare (1955) and Stein (1957). Huxley and co-workers (1964) have suggested that the condition is genetically determined, and Moran (1965) further concludes that there are real class differences in the frequencies of the genes controlling this trait. He also suggests that if schizophrenia is controlled by a simple 2 allele genetic locus, it may be that the heterozygote has some selective advantage. This would account for the maintenance of schizophrenia in the population.

It is comparatively easy to accept the association of social class with abstract concepts such as intelligence or deleterious conditions such as schizophrenia. The possibility of associations between social class and anatomical variations may seem at first view to be remote. But the weight of evidence from previous workers leads to the conclusion that physical differences between class groups do occur, as these have been noted by the majority of investigators. It is perhaps unfortunate that such workers have tended to concentrate on variables such as height and weight. In view of the ongoing 'nature versus nurture' argument, social class differences in such variables will always be open to interpretation as the results of nutritional or other environmental differences. This view could not be taken for the association of a factor not subject to environmental influence with social class variation, and it is disappointing that Dawson (1964) found negative results for his social class study of blood group data in Dublin. Most of the previous reports of positive associations of social class with physical characteristics will be discussed in their appropriate sections, but two important studies will be mentioned here. Schreider (1964) found that French peasants differed from other workers in a large number of physical characteristics, the peasants being shorter and squatter than non-agricultural workers. A study of Flemish youths by Cliquet (1968) showed that many physical variables including height were positively associated with upward social mobility.

Several workers have already shown that associations between anatomical and psychological variations can occur. Schizophrenia has been linked with finger print patterns by Mellor (1967) though Singh (1967) could not confirm this. Cattell and co-workers (1964) found an association between one factor in a personality questionnaire and the ABO blood system. Earlier workers have suggested an association between ability and pigmentation. Ellis (1904) found that on the evidence of the eye colour of portraits of famous persons, scientists and reformers were lighter pigmented than artists, poets and actors. Bramwell (1923) expanded this theory to propose that the different regions of England produced different mental types. Cattell (1946) proposed that those of Nordic and Mediterranean appearances would differ in their abilities and personality traits, with the Nordic type tending to gain higher social status. These theories were revived by Vandenberg (1965), who mentions the possibility that scientists tend to possess blue eyes while those in the non-scientific field are brown eyed. Vandenberg and Kelly (1964) found evidence of hereditary components in vocational preferences.

Thus it would seem possible to relate anatomical differences to social class differences, despite the uncertain nature of the social class variable. Such differences could occur by reason of an association of some success ability with a particular characteristic, or as in the case of the religious isolates studied by Glass and co-workers (1952, 1956) differences might occur by separation of the gene pools of the populations.

1B Investigation of Human Population Differences

Having established the feasibility of the search for genetic differences between human social class groups it remained to decide the method of approaching the problem. Attempts to analyse the genetic variability of human populations are often confused by the complexities of the situation; Mather (1963) noted that classical genetical techniques could not be used with most human populations, though demographic analysis could give valuable data. Barnicot (1963) has discussed the problem of defining the term race with regard to human populations. He feels that if races are specified as interbreeding units which differ from one another in the incidence of one or more genes it would seem probable that some differences could be found between any two populations studied. Barnicot suggests that it would be possible to create a scale of differences which could act to give arbitrary divisions of populations into races. In the present case it would seem permissable to interpret the social class groups as potentially different races, since they show limited interbreeding but are thought to differ in the incidence of the genetic factors controlling intelligence (Burt 1959).

Much of the work on the analysis of human population data is concerned with the detection of natural selection in terms of fitness. However it would seem reasonable to apply the same techniques to an investigation of social fitness in terms of social success. In present society in an industrial country fitness is rarely expressed in terms of actual physical survival of the individual, but rather in terms of gaining environmental advantages. Thus fitness in terms of social class success will ensure favourable conditions for the offspring of the successful individual, and though the offspring of the unsuccessful are unlikely to fail to survive they will be relatively handicapped in any future struggle.

Various techniques for detecting human population differences have been proposed. Van Valen (1963) suggested that differences due to natural selection might be detected by studying the frequencies of well established genetic polymorphisms such as PTC tasting in different age groups. This technique was used by Gorden and Riser (1966). Alternatively he proposed that a study of a limited age range might allow the components of fitness to be related to phenotypic differences. Van Valen also noted that failures to detect selection with regard to a trait were also of value.

Hiorns and Harrison (1970) noted that the sample sizes required to detect population changes in genotype frequencies are often impratically large. They agree with the proposal of Van Valen, that age group differences could show the effects of selection, and also suggest that differences in the mating structure frequencies from generation to generation could follow the differential selection. Kalmus (1963) has provided a table to show the sample sizes needed to demonstrate significant population differences. He shows that where the gene frequency is low, and the difference between the populations is small, very large samples are required.

Morton and fellow workers (1966) gave a comprehensive list of possible modes of analysis of population data. They suggest that the data should be examined for differences from Mendelian segregation ratios, and for departures from the genotype frequencies expected by the Hardy-Weinberg equilibrium. In addition to the comparison of various age groups they suggest that sex differences in particular traits should be noted, and that fertility and mortality differences between genotypes should also be investigated. Any association between genotype and a specific type of morbidity of susceptibility should be studied, and environmental differences between populations of high and low gene frequencies are also relevant.

Unfortunately many of the suggested approaches, though valid in theory, are impracticable for any small scale undertaking. The problem of collecting a sufficiently large sample has already been mentioned, but in practice it is found that the major difficulty is not the collection of data, but the subsequent analysis of that data. Present experience has shown that even a survey initiated with modest aims will be found to proliferate a vast quantity of data which must then be evaluated. Though use of computer handling of data is essential to lighten the task, there are often problems involved in such procedures. The acquisition of large quantities of results may also provide problems. Morton and co-workers also point out that spurious positive associations will occur, especially when a large number of comparisons are being carried out. In their work 739 tests gave 33 significant results, but as this is rather less than would be expected by chance, Morton and co-workers chose to reject these results. Such caution must always be observed, but it would seem impossible to differentiate between real and false significant associations in any set of results.

A further problem in investigating population differences in man is the choice of the genetic variables for study. It has been shown that genotypes that occur in the population in low frequencies necessitated very large samples for the detection of statistically significant differences. Barnicot (1963) advises that workers should concentrate on single clearly defined loci as a first approach to population studies. However, Hughes (1963) puts the case for the use of polygenic characters, pointing to the fact that many of the traditionally discontinuous variables such as hair pigmentation are in fact varying in a continuous distribution. Hughes accepts that there are difficulties involved in the analysis of polygenic variables, but he feels that this problem may be solved by techniques of multivariate analysis in the future.

At present most evidence of natural selection in man comes from blood grouping data. Mourant (1959) and Boyd (1962) have noted the increased susceptibilities of the different ABO blood groups to various diseases. It has already been noted that Dawson (1964) failed to find any association between blood groups and social class, but it may be relevant to consider the non-random nature of Blood

Transfusion Service Data. All surveys short of the National Census fall short of perfection in that there is no compulsion for subjects to take part. Thus any sample is to some extent self selected. This is particularly true of the B.T.S. data, as blood donors form a small minority of the general population, and may have temperamental differences from non-donors. An apparent sex difference in B.T.S. data was noted by Fisher and Roberts (1943). Nevertheless the B.T.S. data is of great value, and it was hoped to use such data in the present project as an additional measure of social class variables. Unfortunately the time available did not allow this.

In reviewing the previous work on genetic variation it was surprising to discover that no full investigation of possible differences in human polymorphic traits between social classes had been attempted. Such differences, if proven, could provide uncompromising evidence that the social class groups were genetically different. The majority of polymorphic traits are thought to be less susceptible to environmental influences than are the metric variables such as height and intelligence, and thus the complication of environmental differences would be avoided.

It had however been noted during the literature survey that very little data relating to the heritability of commonly utilised polymorphic traits was available. As an addition to the original survey plan it was therefore felt necessary to establish the level of heritability of any trait to be used by means of a twin study. Though it was realised that such a study could easily form a major project it was felt worthwhile to incorporate a small-scale study within the main project in order to validate any conclusions that might be reached.

Since there was an evident lack of data relating polymorphic traits to social class it was felt that the most generally valuable method of testing the present hypothesis would be to undertake such a survey. In essence this approach utilises one of the plans suggested by Van Valen, as it was decided to use a limited age range of subjects and include a wide range of characteristics. In addition to the standard polymorphic traits certain metric variables were to be included in order to provide a point of reference with previous work.

The basic rationale of this project is the inversion of the standard methods of the anthropologist to investigate the possibility of population differences within the investigator's own environment. Such a project is of necessity interdisciplinary in nature; in this case aspects of sociology are to be included in a project that is basically biological. One difficulty encountered in attempts to integrate these two points of view is that the majority of sociologists have no clearly defined theory on the basis of social class, though most would relate it to the effects of environment. While social classes may be defined by various methods the nature of the categories defined is not clear.

From the view of the biologist it is therefore necessary to accept the existence of the social class groups as a valid concept.

It is then possible to propose that the social ecology of the individual within the social class strata may parallel the formation of ecotypes within a plant species.

If it is possible to show that social class grouping can be interpreted in terms of population genetics then this would be a most valuable contribution to the whole comprehension of the social class system. This biological approach to a problem of sociology might ultimately play its part in developing the interconnection between the two subjects. However owing to the present lack of contact it is probable that any such biological approach will be met with some apprehension by the pure sociologist. It is important that such reservations must not hinder the full investigation of possible population differences in the social class system.

2 METHODS

2A - Design of Experiment

2A.1 Original Survey Plan

The survey reported in this account is not the original experiment that was planned. As the original plan was only abandoned at the end of the first year it seems appropriate that a brief summary of it should appear in this report. It may be that the original survey plan had some influence on the actual survey that was carried out. If this work had been devised as an original project rather than a substitute the procedure might have differed in certain respects, for instance the definition of the regional samples. Certainly more time would have been available.

2A.2 Design of Original Survey

It was decided to study the population of English males between the ages of 30 and 34 who were domiciled in Birmingham and its environs. The object of the survey was to compare the frequencies of a range of inherited physical traits in groups of men from the extremes of the social prestige scale. A lower age limit was set in order to obtain a sample of men who were settled in their occupation, and the age range was restricted in order to eliminate age differences as a complicating factor.

In this survey English was to be defined as having both parents born in England and all four grandparents born within the United Kingdom. In order to obtain a comparable sample of adult females, the wives of the male survey subjects were to be included in the sample. All the wives were to be seen, even those not classified as English, as it was hoped to obtain information on assortative mating for the traits under study.

The same range of traits that were to be included in the original survey was used in the substitute survey. A full discussion of the choice of traits is given later (see section 2E.1). The only trait that was not appropriate to the substitute survey was that of baldness; this feature only normally being present in adults.

The higher prestige end of the social class scale was to be represented by two groups of men representing the professional elite and the business elite. It was hoped to define these groups by use of the Registrar General's Classification of Occupation, the Hulton Readership Classification and in some cases by income level. These classification methods are discussed elsewhere (see section 2B.3). A list of sample occupations to be included in these groups is given in the appendix (table A8). Similarly the less privileged end of the social scale was to be represented by two groups, one of urban manual workers and one of rural manual workers.

In addition to information on the physical traits included in the survey it was hoped to collect background information about the occupations of the parents of both husband and wife. Once the data had been collected it would have been possible to extract the following information:

i) total frequencies of the various traits in the English population

ii) differences in frequencies between the social class groups

iii) differences in frequencies between the sexes (non-English wives excluded

iv) estimates of assortative mating for physical traits

v) estimates of assortative mating for background variables

vi) estimates of social mobility

vii) associations between pairs of physical characteristics.

It was hoped to interview a total of 250 men in each of the four groups, and it was expected that approximately 80% would be married. In data from the Registrar General's Survey (1961) it was found that 77% of the Birmingham males in the age range 30-34 were married. This would have given a final sample size of 1,800. Since the total population of SC I and II males in the appropriate age range living in Birmingham was only 5,066 (Registrar General 1961), it may be that the survey plan was over optimistic in hoping for interview a specialized 10% of this total. However it was anticipated that these groups would be more co-operative than the lower prestige groups. Only 250 manual workers were required from the City's total of 10,096 of the right age; this would have meant interviewing 2.5% of the total. The remaining 250 were to be found in the rural areas surrounding Birmingham.

2A.3 Sampling Methods

Any attempt to achieve random sampling in a survey such as this is complicated by the need to bring the subject into contact with a range of apparatus. It was therefore not possible to undertake a simple doorstep approach. Though it would have been theoretically possible to transport all the apparatus from door to door this would have been a strenuous task and it would have meant gaining the co-operation of the subjects in order to set up the apparatus within their houses. These factors were combined with the added difficulty of contacting employed men as they would only be available at home during leisure hours.

The Centre for Urban and Regional Studies of Birmingham University were contacted for advice on this problem. They suggested that use of the Census Enumeration data would enable the investigator to select small areas of the city where there was a high probability of finding the desired social class groups. These areas would then be sampled using the Voters' Register. But although this method would have narrowed the search area it did not solve the basic transport difficulties. The narrow age range required in the survey meant that even using the Voters' Register and the Census Enumeration Data the majority of the households contacted would not meet the survey requirements. It was hoped at this stage to obtain a truly random sample and there was some doubt about sampling only from selected areas of the city.

It was realised that the most economical method of collecting the data would be to arrange for the subjects to come to the apparatus rather than vice versa. However it was not possible to pay fees and travel expenses to the subjects, and so the survey could not be based at the University. It was decided to approach employers in order to ask for their permission to interview appropriate members of their staff.

A random sample of the employers in Birmingham was required. On contacting the Area Office of the Ministry of Labour the officials offered to allow the investigator to copy names of employers from their lists. These lists divided the city into six areas, but the firms on each list were scattered throughout the area. It would have been possible to obtain a random sample of firms from this list, but it was decided that the transportation of the apparatus would still present difficulties.

It was decided that it would facilitate the survey procedure if areas of the city were randomly sampled and then the firms within these areas were contacted. A map of the city was obtained and the area within the city boundaries was divided into small sectors of between 1/6 and 1/3 square miles. The total number of sectors in the city was 258. The boundaries of each sector followed the paths of roads and road junctions where possible. Each sector was given a number and then 10% of the sectors (26) were chosen by means of random number tables. The streets within each area were defined from the map and then the names and addresses of employers with premises on these streets were obtained from the current edition of Kelly's Directory (1967-68). This Directory lists all the occupants of all but the most recently built streets.

A letter was prepared explaining the survey and asking permission to interview a small number of workers at some convenient time. This letter was sent to the Public Relations Officer at each firm approached. In the letter it was emphasized that only a few of the firm's employees would be required, and each one would only be needed for approximately ten minutes. It was also suggested that the survey could take place during the dinner hour or rest breaks if preferred. (specimen copy table A2)

A first batch of 30 letters to firms produced only two refusals, the remainder ignoring the approach completely. A further 25 letters produced a single offer of one subject. It was therefore decided that the random sampling technique would have to be abandoned as this involved contacting mainly small sized firms whom it appeared were not co-operative. Since there are almost 4,000 different employers in Birmingham but only 200 with more than 500 employees (Ministry of Labour data 1968) the chances of these large scale employers being included in a random sample is remote.

It was decided to contact the largest firms and organizations in Birmingham, and also to approach specialist firms such as Industrial Cleaners almost all of those employees would have been classified as unskilled or semi-skilled. It was decided to concentrate at first on obtaining the urban manual group, as it was felt that a group of professional men could be obtained from the city's two Universities with comparative ease. In some cases the approach to large firms met with initial success, as the Public Relations Officer agreed to the survey in principle. However when the suggestion reached the shop floor there was a unanimous refusal. Even firms with normally good public relations were unwilling to allow the survey to take place. A list of employers contacted is given in the appendix (see table A1). As a final attempt the working mens' clubs in the city were contacted and asked whether the survey could be carried out on their premises during their opening hours. None of the clubs would agree to this, though a free lecture was offered as an incentive.

During attempts to obtain a rural group of manual workers the National Farmers' Union and the National Federation of Womens Institutes were contacted. Neither of these organizations was prepared to offer any assistance in the survey.

It was therefore decided that the survey plan would have to be modified, as there was no prospect of obtaining a sample of manual workers. Since the basic motive of the survey was to compare different social class groups, the lack of adult manual worker groups meant that it was purposeless to collect an adult professional group.

The negotiations with employers took place during the whole of the first year of the project. At the same time the experimental methods were being worked out and tested and a computer program was written to cope with the expected data. The pilot survey took place towards the end of this period.

2A.4 Substitute Experiment

Since it proved impossible to obtain adult samples of different social class this left two possible sources of subjects; students and schoolchildren. Neither of these populations was ideally suited to a study of social class as both are classified on the social class rating of their father, having no social class rating of their own.

Although the student population was easily accessible it was decided that it could not be used in the present survey. Students are a very highly selected group and on the basic hypothesis of this investigation the student population would be expected to be more homogeneous than the general population. It would therefore have been unwise to use the University population, particularly as a previous survey (Wheatcroft 1967) had only found social class differences for one trait in a student survey.

The only remaining source of subjects was the school system. One advantage of using secondary school children as opposed to students is that it is possible to classify them by the type of school they attend. This gives an indication of the child's ability and so it can be used as a partial substitute for social class. Though it is possible to classify children according to their father's social class this method of division takes no account of the children who will be socially mobile in either direction.

It was decided to sample children at the maximum age that an unselected sample can be obtained. In practice this meant the age range fourteen to fifteen, as the least able children tended to leave the secondary modern school at fifteen and the grammar schools at sixteen. It was felt that for ease in conducting the survey the children should be as old as possible in order to obtain accurate answers and full co-operation.

2A.5 Organization of Sampling

A list of all the secondary schools in Birmingham was obtained from the Local Education Authority. It was decided to exclude specifically Roman Catholic Schools as these schools in Birmingham have a very large proportion of children from Eire. Since the majority of the immigrants from Eire are manual workers, it was felt that the inclusion of many of their offspring in the sample would confuse the social class issue.

This left a total of 33 grammar schools and 72 secondary modern schools. It was decided that comprehensive and bilateral schools would not be included (see schools visited table A4). The majority of the city's 33 grammar schools are single sex schools, whereas the secondary modern schools are approximately equally divided into boys', girls' and mixed schools.

The approach to the schools was the same in all cases. A letter explaining the survey to the Head Teacher was prepared.

Xerox copies of this letter were made and then the Head's name and address were filled in as appropriate. The total effect was very near to that of an individually typed letter. In the original contact letters the schools were offered a free lecture in return for their co-operation. (specimen copy table A5)

A very good response was obtained from the grammar schools. Many laid down strict conditions about the times of the visits. In some cases the survey was only allowed during Biology periods or during the lunch hour. In all visits were made to 8 boys' grammar schools, 6 girls' grammar schools and 3 mixed schools. In fact it was discovered that one comprehensive school had been misclassified as a grammar school but in this case the sample was taken from the grammar school stream.

In approaching the secondary modern schools preference was given to the mixed schools. Letters were sent to the Head Teachers of all the mixed secondary modern schools first, and then when it was found that more schools would be needed some of the single sex schools were used. A total of 20 secondary modern schools was visited, of these 17 were mixed, 1 boys' and 2 girls' only.

In many cases it was necessary to make more than one visit to a school. This was usually the case where very strict rules had been laid down about the timing of the visits. In all 59 visits were made to the schools, however this includes one fruitless visit paid to a school who had forgotten that the appointment had been made. It was found that the secondary modern schools were less rigidly bound by the time-table than were the grammar schools, and they were more prepared to disrupt lessons so that the survey could proceed. In some schools a pupil was withdrawn from classes and told to act as a runner fetching other pupils to the survey room.

When the Head of a school gave a favourable reply to the initial letter he or she was contacted and a date and time for the visit was arranged. In some cases this was not possible as the school wished to hold the survey in reserve for a rainy games day, while others could not give any long term plans for their pupils and asked that they should be contacted again later. School examinations were another complicating factor as some schools wanted no distractions at these times while others preferred that the survey should take place while the school time-table was disrupted. After the arrangements for the visit had been made the Head was sent a set of explanatory letters to distribute to the childrens' parents by way of the children. These letters asked for the parents to sign a consent slip and return the slip to the school. (see specimen copy table A6)

It was hoped to obtain about 20 subjects from each school visited and in practice it was calculated that approximately eighteen subjects was the average per school. There was a range of variation between thirty subjects from the most productive schools and only one from a school in a very deprived area. Absenteeism was mentioned by staff as a problem in the non-selective schools, but not in the grammar schools.

2A.6 Survey Procedure

It was found advisable to telephone the schools the day before the visit to check that all the arrangements were in order. Apart from sending the parental consent slips to the schools the basic organization of the interviewing at the schools was done by the various members of staff to who much gratitude is owed. The interviewer arrived at the school fifteen to twenty minutes before the interviewing was due to start. The apparatus required for the survey was carried in a large suitcase and a large holdall; the folding height measure being carried separately. The interviewer's own van was used for transporting the apparatus in most cases, the vehicle having been purchased expressly for this purpose. When the van was under repair owing to a breakdown the interviewer and the survey apparatus were transported to the schools by the University minibus, technician's private cars or, exceptionally, by taxi. The large quantity of survey apparatus made it impossible to use public transport. (see table A8 List of Apparatus). On arrival at the school pupils were often deputed to help carry the apparatus into the building. This was fortunate owing to the complex patterns of some of the school buildings. Since most of the schools visited were acutely short of space the survey was carried out in whatever room was available. This included the headmistress's study, the library, the preparation room, the sick bay and the back of the laboratory in which the remainder of the class were being taught. Sick bays and laboratories were most convenient to work in as they had easily accessible power points and sinks. When no sink was available it was necessary to keep the discarded PTC solutions in a 'slop bowl' and either dispose of this waste liquid at some interval in the interviewing or else pour it into specially labelled waste bottles and take it back to the University for disposal.

The pupils were interviewed singly. In general the school staff provided a list of names and the first person to be interviewed fetched the next on the list. At some schools an appointments system was worked out by the staff. Though it would not have been reasonable to expect this service of all the schools it was noted that the schools where the pupils were given appointments managed to provide the largest samples. In schools where the organization was less good there was sometimes some confusion and time-lags between the subjects. One case occurred where a boy was sent along to the survey room and completed the survey before it was discovered that he was not in fact the boy whose consent form had been received but merely another of the same name.

2B - Background Data

2B.1 Collection of Data

It was necessary to establish whether the subjects could be included in a sample representing a British population, and also the nature of the survey made it imperative that the subjects' social class background should be known. These two questions (which were included in the survey as 'parents' birthplaces' and 'father's occupation') represented the minimum possible social enquiry necessary for the survey. Nevertheless even this apparent attempt to probe into the subjects' background provoked some very hostile reactions, not from the subjects but from their teachers. In fact an explanatory letter was sent out to all the parents (see table A6) and those children who did not wish to do the survey simply did not return the consent slips on their letters.

The consent slip attached to the letter asked firstly for the parent's signature, and then asked the parents to provide if possible details of their and their parents' places of birth, and also the occupation of the child's father. It was thought that this information would be more accurately obtained directly from the parents, and that the parents should be given a chance to object to the questions if they wished. The majority of the consent forms that were returned were filled in most conscientiously, sometimes with full addresses for place of birth. When the child had lost or soiled the consent form this was often carefully copied out onto a piece of clean paper and presented to the interviewer with great pride. The age of the child was also filled in on the consent form. The object of this was to avoid children putting down the wrong age on the consent form in order to be included in the survey. It was found that the majority of the children welcomed the disruptive effect of the survey.

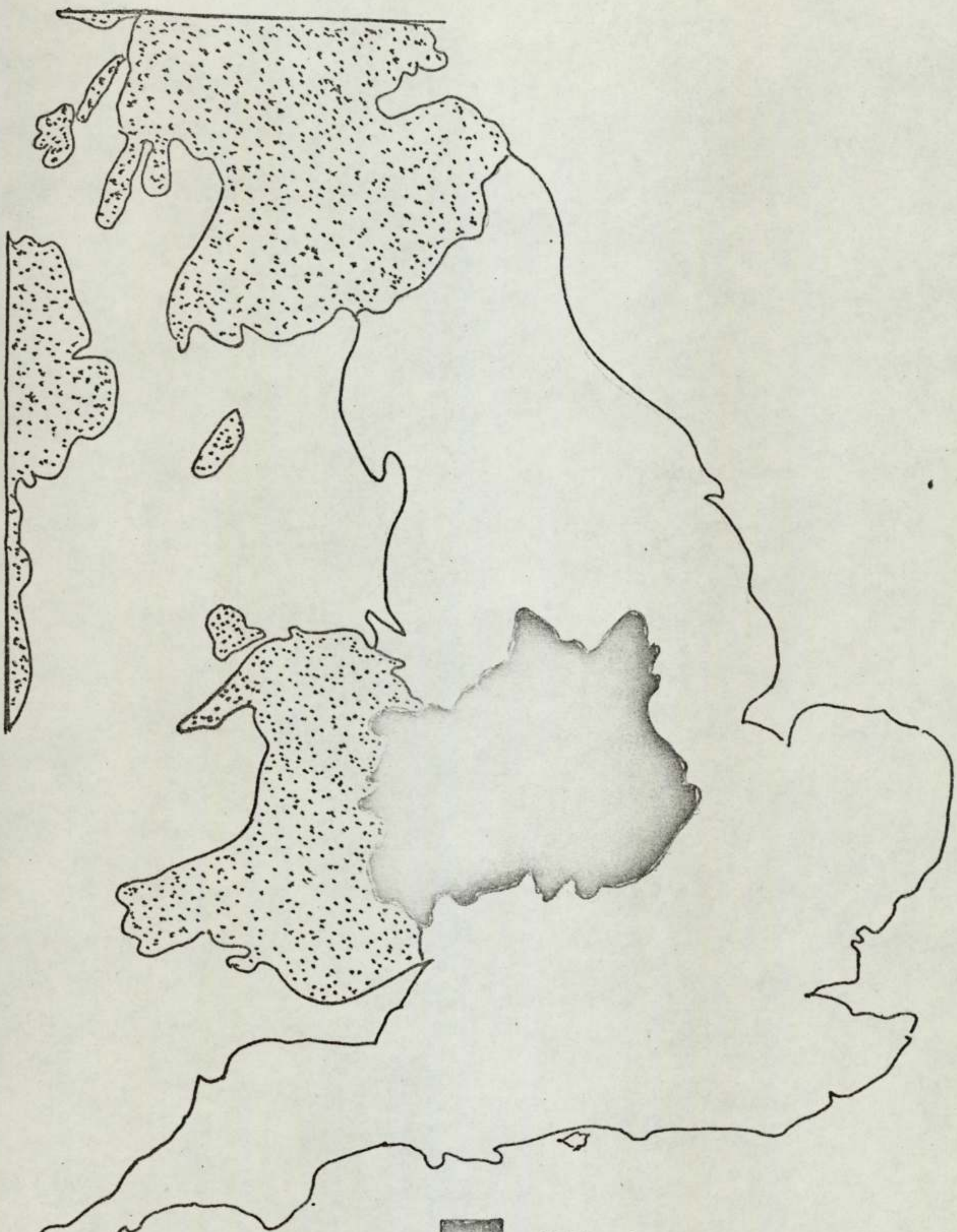
There were therefore four main sections of background information for each child. Geographical origin (in terms of parents' and grandparents' birthplaces) and social class background were obtained from the parental information. The type of school attended, grammar or secondary modern, was recorded at the time of the survey, and the sex of the pupil was also recorded at this time.

2B.2 Geographical Background

It was decided to classify the birthplaces of those born inside the UK as Midland, English or British. In this classification Midland included all those born within the counties of Staffordshire, Worcestershire, Warwickshire, Shropshire, Herefordshire, Derbyshire, Nottinghamshire, Leicestershire and Northamptonshire. The original reason for this classification was that this was the area covered by the local regional offices of the Ministry of Labour and it was hoped in the first survey plan to sample from workers in this area. The 'Midland' area defined in this survey therefore contains the whole of the Midland Region and a part of the North Midland Region of the Registrar General's Classification (1961). 'English' was defined as being born within England but not in the area defined as Midland, and 'British' was defined as being born inside the United Kingdom or Eire but not in England. (see fig.1)

Those who were born outside the United Kingdom were

Fig. 1. Map to show classification of parental origins by region



classified into three main groups: Asians (including Kenyan Asians), West Indians of negro ancestry and miscellaneous Europeans. No Chinese or Africans were encountered despite the city's small population of these groups.

Since each child has two parents the classification of his or her origins needed to take into account both their birthplaces. The parents could both be Midland, English or British, or they could be one Midland and one English, one Midland one British or one English and one British. In other cases one parent could be Midland, English or British while the other was Asian, West Indian or European. It was also expected that some of the subjects would be of Asian or West Indian descent alone. If the parents' place of birth was not known this was counted as being not United Kingdom unless further information could be obtained at the interview.

As the efficient working of the survey depended on the goodwill of the subjects it was decided that the interviewer would accept any subject who offered his or herself with a filled in consent form. In practice this meant interviewing a small number of children who had only one parent born within the U.K. and who would therefore be rejected from the survey sample. Asians and West Indians were accepted for use in a separate sub-survey, but in fact very few of these groups were seen.

In order to simplify the classification of the parents' birthplaces for statistical purposes the classes of United Kingdom origin were summed together to form parentage groups. The Midland group included only those with both parents born in the Midlands. The English group contained those with two English parents or one English parent and one Midland parent. The British group contained the remainder of the U.K sample: those with two British parents or one British and either one English or one Midland parent.

Each child also had four grandparents and therefore the comparable system for classification of grandparents' birthplaces becomes somewhat complex. The full system will therefore not be given here but may be found in the appendix (see table A9).

2B.3 Social Class Background

In working with children it is not possible to give them a social class rating by any of the accepted methods, as all these depend on occupation and earning power. It was therefore necessary to classify the children by their father's occupation as indicating their social class background.

The most commonly used system of classification is the Registrar General's Classification of Occupations (1961). This provides a comprehensive list of occupations and divides them into five social class groups. I professional; II managerial; III skilled manual; IV semi-skilled manual; and V unskilled manual (see Table A3 for list of sample occupations included in each social class). This classification is comparatively easy to use and it requires only the minimum of information. It has been hoped to also include another method of classification, the

Hulton Readership Survey Classification, which is used by the British Market Research Bureau. However when the British Market Research Bureau were contacted they were unwilling to give more than an outline of their system, and it was therefore not possible to use this. In practice it was found that the total in SC I and V were sometimes too low to allow statistical analysis. If this was the case SC I and II were summed to form a group named as 'professional', SC III remained as 'middle class' and SC IV and V were summed to form a 'manual' group.

2B.4.
School Type and Sex

As it was not possible to give the children their own social class ratings it was decided to compare their school type instead. In order to clarify the situation it was decided to take samples only from the grammar schools and the non-selective secondary schools in Birmingham, leaving out the comprehensive and bi-lateral schools. The reason for this procedure was to obtain the maximum possible differences between the two groups of children, as there may be a tendency for the children of most ability to be 'creamed off' into the grammar schools, despite the equal status of the top streams of comprehensive schools.

Although some of the names of the children would have given no clues as to their sex in a postal survey, there was no possibility of confusion in the actual interview.

2C - Method of Analysis of Data

2C.1 Handling of Data

In the original survey plan it was hoped to collect information on 42 variables from a total sample of two thousand. The failure of the first survey plan meant that the sample size had to be reduced, but this was still too large to handle without some mechanical aid. The possibility of putting the data onto punched cards and then using a card-sorting machine was investigated. A visit was made to the Cancer Records Unit of the Queen Elizabeth Hospital in Birmingham. This showed that although this method would have been usable it would have needed a long period to carry out all the tabulations desired.

It was therefore decided to use a computer to handle the survey data. The University Computer Centre advisory service were consulted, but although they were most helpful they were more familiar with mathematical problems than with survey work. They suggested that it would be useful to consult the computer specialist of the Applied Psychology Department at the University, a Mrs. Jean Abbott, who had wide experience of handling survey data. Mrs. Abbott suggested that the present survey data should be handled using the Multiple Variate Counter Program, which had recently been devised by the University of London Atlas Computing Service.

2C.2 The Multiple Variate Counter Program

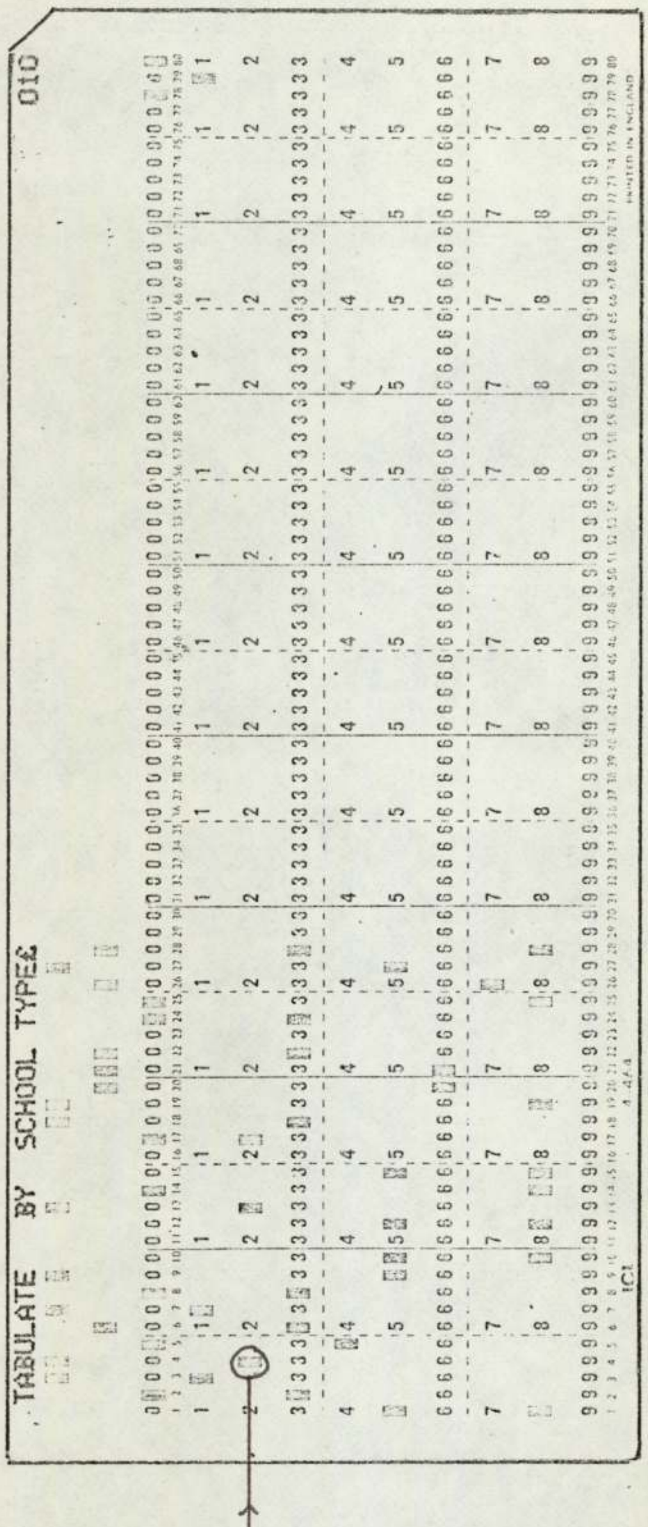
The Multiple Variate Counter program is a general purpose program designed for use with surveys such as the present one. The purpose of the program is to allow even the novice investigator to make use of computer facilities in survey work. As it now stands the MVC program is a most valuable tool. However some difficulties were found when it was first used as there were program system changes from week to week. Certain facilities in the original program were withdrawn and these have not been replaced.

The MVC system accepts both data and program as punched cards. The standard card is divided lengthwise into 80 columns, and each column is subdivided into twelve parts. These twelve hole sites are known as U, L, 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9; U being the top hole site. This gives a total of 960 possible hole sites on each card. Each hole site on the card is identified by its column number and its hole site number. The uppermost hole site in the first column is therefore identified as 1/U. (see fig.2)

2C.3 MVC Specification

The first step in using the MVC system is to describe the expected data in terms that will be acceptable to the computer. The data may be either "raw" or "derived" variables. If a variable is raw this means that it corresponds directly to the value obtained from the subject and fed into the computer via the punched cards. A derived variable is one that is formed from raw variables appearing on the questionnaire; the derived variable is not obtained directly

Fig. 2. Illustration of punched card



hole site number 4/2

from the subject.

Three types of variable are allowed in the MVC system, and each type can either be raw or derived. Numerical variables are those which have ordinary numeric values. In defining a raw numeric variable one column is allowed for each digit of the variable, and the number is punched onto the card using only the 0 to 9 hole sites. In the present survey height, weight and other continuous variables were defined as numerical variables. Ponderal index is an example of a derived numerical variable. This was not obtained from the questionnaire but is formed by the computer from the relevant data.

When a variable can take only one answer out of several possible answers this is defined as a polylog variable. In the present survey eye colour was a polylog variable. A raw polylog variable is defined by stating the column and hole site in which it begins, the number of possible answers, and if required the names of the various answers. Thus in eye colour the answer names were blue, blue-grey, grey, etc. A derived polylog is usually formed by a modification of one or more raw polylogs in the computer to form a new variable. In the present survey eye colours were lumped together into light, mixed anddark by this method. It is also possible to obtain derived polylog variables by dividing up a continuous, numerical variable into classes. This was also done in the present survey when it was necessary to compare continuous and discontinuous variables.

The third and simplest type of variable is the binary variable. This represents a question that only has one of two possible answers. A raw binary variable is defined by giving a single hole site identification number. For example in the present sample each subject either had or had not given a hair sample. This was defined in the program as Hair Sample 36/0. If this hole was punched it meant that there was a hair sample for the subject and if it was not punched, there was not. No derived binary variables were used in the present survey, though it would have been possible to use one in defining the population as United Kingdom or not United Kingdom.

When all the variables have been defined they are added together to form the survey specification. This specification defines and names each variable and states the positions on the punched card in which the raw variables will be punched, and the origins of the derived variables.

It is possible to use computer instructions (system words) to skip various parts of the specification in certain cases. In the present survey some subjects did not provide a hair sample. The specification allowed for this by skipping the relevant variables if the hair sample was absent. In defining derived numerical variables it is possible to use arithmetic relations and expressions. Various instructions are used in defining derived polylogs and binary variables.

2C.4 Questionnaire Preparation

The questionnaire, or rather in this particular survey the record sheet, is prepared in such a way that the details of the various traits can be punched onto cards by the punch operator. In this case the right hand margin of each record sheet was devoted to answer boxes. Each box had the appropriate column number for the numerical variables, and in the case of polylogs and binary variables both the column number and the hole site number were provided. Answer boxes were provided for all the possible polylog answers with their names beside them. In the actual interview the numerical answers were written in the appropriate boxes and the polylog and binary answers were noted by means of a tick in the appropriate answer box. The program only accepts numerical variables as positive whole numbers. It was therefore necessary to put in the continuous variables as ten times their actual value and then adjust this by deriving new numerical variables from the raw originals (see specimen Survey Sheet table A7).

2C.5 Number of Cards Per Person

In the present survey only one card per person was required to carry all the necessary information. However the first program that was written using the MVC system was designed to cope with the expected husband and wife pairs of the original survey plan. This was a more complex programme than the present one, but even this only required two cards per couple. In larger surveys many cards may be needed for a single case.

2C.6 Analysis of Data

Once the specification of the variables has been completed it is possible to request any tables of results to be printed by the computer. This is done by means of table specifications. Certain system words are used to instruct the computer to form and print the tables required. It is possible to exclude classes from the tables as necessary, and it is also possible to obtain other results in terms of percentages. In practice it was found that the use of the percentage facility required much forethought, as it was possible to obtain percentages expressed in terms of rows, column or entire tables. The presence of individuals with unknown responses also complicated the percentage situation, as such tables had to be repeated after removing these cases.

In the case of numerical variables it is possible to obtain the means and standard deviations of the groups required by specifying these calculations in a table. The correlation between any two or more numerical variables can also be given. For statistical analysis of the discontinuous data the chisquare test can be specified. If the program receives a list of polylog names with the appropriate chisquare instructions it forms a contingency table for each possible comparison and then prints a triangular matrix of chisquare values. Yates' correction is applied when a 2 x 2 contingency table is calculated. If the theoretical value for any cell of a contingency table falls below five a question mark is printed beside the answer.

The significance of the results in the chisquare and correlation table is indicated by means of asterisks. No asterisk means that the result is not significant, one asterisk means $0.05 > p > 0.01$, two asterisks means $0.01 > p > 0.001$ and three asterisks mean that $p < 0.001$.

2C.7 Use of the MVC Program and Computer Facilities in the Present Survey

After it had been decided to use the MVC program an immediate start was made on writing the program, as it was felt that the maximum time should be allowed for the writing and testing of the program in view of the inexperience of the investigator, who had not previously used any form of computer. The writing of the program for the original social class survey was carried on at the same time as attempts were being made to obtain an adult sample and survey methods were being devised.

A program was written and checked by Mrs. Abbott. This was then punched onto tape by the Aston Computer Centre as the ability to accept the program specification on cards was a later addition to the original MVC system. The tape was then corrected and sent to the Science Research Council Atlas Computer at Chilton, Berks. Another useful facility of the MVC program system is that it will check new programs and print out any errors with their line number and a comment of the type of fault present. A number of errors were detected in this way, and so the program was returned to Aston for correction. Several computer checks were necessary before the program was fully accepted, as each correction session gave rise to further errors.

When the program was correct a few data cards were fed in and then rejected whereupon all their data was printed out. The purpose of this was to obtain a complete record of the data for each case as it was interpreted by the computer. These records were then checked against the original data to make certain that no errors had occurred. It was found for example that the values for height and weight had become reversed at some stage, so that the computer was interpreting the value for weight as height and vice versa. This was corrected, and then the first run of the program was carried out using the data from the pilot survey. (The pilot survey had been carried out towards the end of the program testing). Satisfactory results were obtained from this first run and so it was hoped to use the program in the main survey.

However it then became apparent that the original survey plan could not be used. This made it necessary to rewrite the original program to fit the new survey plan. Fortunately this was a matter of simplification rather than expansion as the new survey covered single individuals rather than linked couples. The program was then re-tested and the pilot survey data was re-run as a check.

Concurrently with this the collection of the main survey data was going on. The major part of the data was filled into the answer boxes at the time of the interview. The information about the subject's background was added at a later date, as this was presented on a separate strip of paper. There were also answer boxes relating to the reflectance spectrophotometry of the hair sample which could not be filled in until the analysis had been completed.

When the collection of the sample was finished the record sheets were checked for errors and missing data. Owing to difficulties the reflectance values for hair colour could not be filled in at this stage, and so it was decided to put the data onto cards and then add the hair-colour values later. The record sheets were therefore passed on to the University of Aston Computer Centre, who punched the cards.

When the cards were returned they were checked to ensure that the cases were in order, (this is a requirements of the MVC system), and then sent to the SRC Atlas. In addition to checking the program for errors the MVC system also checks for errors in the data and rejects the faulty data with an indication of its faults. Some of the data was rejected on the first run and sent back to Aston for correction. These faults were corrected by the investigator and the cards were then replaced in order in the main body of the data and returned to the Atlas.

The first batch of tables was soon received. From this time until the final stages of the project new sets of tables were being sent to the Atlas and new results received. The reflectance measurements of hair colour that were expected were unfortunately not available. It was necessary therefore to re-write the short section of program that would have dealt with these values, substituting specifications of the Munsell colour system values that were used. Some further derived values were added to the basic specification during the course of the study. Throughout the whole period of use of the Atlas Computer, the MRC specialist there, Mrs. Judith Lay, gave invaluable help and advice.

There was only one inconvenient point in the use of the MRC system. For some reason that none of the Atlas advisers could explain, the chisquare matrices were formed with every number accompanied by a question mark. As mentioned above (2C.6) this is supposed to indicate that the comparison has some theoretical value below five, but in this case the question marks bore no relation to the theoretical values. This meant that it was necessary to repeat the calculations for all the significant chisquare answers in order to check this by use of less sophisticated calculating facilities.

2C.8 Use of The Olivetti Programma 101

At about the same time as the project was started, the Department acquired a desk top computer, the Olivetti 101. This machine has a limited memory and can be programmed to perform statistical and other calculations. It was decided that as the investigator would be using the calculator extensively she should attend a four-day training course run by Olivetti, in order to learn to program the machine.

In basis the Programma has ten registers, three which are used in calculation, five which store numbers and two memory stores. Instructions are stored in the memory but can overflow into three of the five number storing registers. Each number sorting register can hold two 11 digit figures, and each memory store can hold 24 instructions. A program can be transferred from the memory onto a program card and stored in a similar manner to tape recording.

Programming this machine involves the use of the basic mathematical expressions +, -, x, ÷ and square root, and manipulating the sub totals among the available registers so as to obtain the desired result. This machine proved very useful and many programs were written for it. These included a 3xn chisquare, Kolmogorov-Smirnov test, Ponderal Index, Heritability (and variance ratio) and a 't' test using means, standard deviations and totals. This last test was used to test for significant differences in the continuous variables, as only means and standard deviations were available from the MVC system. The 3 x n chisquare, the 2 x n chisquare (from the Olivetti programme library) and a 2 x 2 chisquare with Yates modification produced by the investigator were all used in checking the chisquare results from the computer and also in the twin survey. The Kolmogorov-Smirnov Test was used in certain comparisons where a continuous variable was being compared with a discontinuous one. At a later stage of the project a small sample of twin pairs was collected. The programs for Heritability and Ponderal Index were used in analysis of the twin sample as it was not thought worthwhile to write a computer program for a sample of 58 pairs.

2C.9 Negative Results in Associations Between Characteristics

Except in special circumstances it has not been thought necessary to include details of non-significant associations in this account. In the case of the non-continuous variables and the divided continuous variables all the possible chisquare comparisons were carried out. The total UK sample was analysed first, and then the male and female sub samples were separately examined. The majority of the variables were included in the testing both in their full form and in at least one shortened form. For instance PTC tasting was included as a 14 class variable giving the subject's threshold number, and also as a 2 class variable dividing the range into tasters and non-tasters.

When a significant result was obtained from the computer analysis the relevant table and associated tables were requested from the computer. The significance was then checked as stated above. If an association was found to be present in one sex only the comparative data for the other sex and the total sample were examined, and this data has been quoted in the report. Cases where previous reports have shown significance but this has not been confirmed by the present survey are also noted.

2D - Pilot Survey

2D.1 Background to Pilot Survey

In order to test the experimental methods and to provide data for the computer program to run on it was decided to undertake a small pilot survey. At this point the original survey plan was still in action, and it was hoped to obtain a sample of employed men and their wives. This proved impossible and so it was decided to use students of the University as subjects.

2D.2 Organization of Pilot Survey

A room was booked at the Students' Union and all the apparatus was set up. Subjects were collected by simply accosting any person passing the room, and when this supply failed the students' common room was visited and subjects were persuaded to help. No attempt was made to obtain a random sample as this was a purely practical exercise. It had been intended that approximately equal numbers of males and females would be collected but owing to the sex distribution of the student population on the Aston campus this proved difficult, as the majority of those willing to undertake the survey were male.

2D.3 Experimental Methods of Pilot Survey

In general the methods used in the pilot survey were continued into the main survey and so may be found under the appropriate sections. In some cases modifications were made in the original methods owing to the experience of the pilot survey. These changes, which occurred in classification of ocular defect, hair colour measurement, height measurement, PTC tasting and laterality, are discussed in the relevant sections.

It was also decided to investigate the possibility of using Sheldon's Somatotype classification on the pilot survey data. In Sheldon's book "Atlas of Men" (1954) he provides a scale for transforming ponderal indices into somatotype classifications. This method of classification is not free from defects as there are often several possible somatotypes for one ponderal index class. However it was decided to attempt to use this scale, though in fact it should only be applied to males, the deposition of fat in females meaning that they would require a separate scale of ponderal index transformations.

2E - Traits Considered for Inclusion in the Survey but Rejected

2E.1 Collection of Traits for the Survey

When it was decided to undertake a survey of inherited characteristics an extensive search of the literature was made. From this a list of possible traits was prepared. As it was realised that the time available per person for the survey interview would be limited, it was necessary to choose certain characteristics known to be genetically determined for study, and discard the remainder. In general, the criteria used in this choice were the degree of establishment of the trait in the literature and the methods used to test for this trait. Although many traits were rejected it seems appropriate to give a brief account of these traits and the reasons why they were considered inappropriate in the present survey.

2E.2 Variations in Taste and Odour Sensitivity

Wiggers (1949) noted that sodium benzoate, which is often used as a food preservative, has a definite sweet or bitter taste to approximately 25% of the population. Harris (1952) suggested that this could be due to a Mendelian recessive factor, but this has not been confirmed. Gorman (1964) also mentions this taste difference. In the present investigation sodium benzoate crystals were tasted by a number of subjects in a preliminary trial, but there was no clear differentiation of the responses into two classes. Since it seemed that a full testing programme was needed to develop a technique of taste testing for sodium benzoate it was decided not to include this trait in the survey.

In a very limited sample of five persons, Lasselle and Williams (1926) and Williams (1931) found that creatine tasted bitter to one subject while the remainder found it tasteless. They noted that this taste difference must affect the taste properties of meats, as there is a large proportion of creatine in muscle. Papp and Makara (1965) found that there was a taste difference between the L and D forms of amino acids, the L form tending to be bitter and the D form sweet, but they did not note any difference between persons.

Some workers have found that there is great variation in the ability to smell potassium cyanide. Kirk and Stenhouse (1953) used 20% KCN on cotton wool in a test tube which the subjects sniffed and compared with distilled water. They suggested that the lack of ability to smell KCN might be inherited as a sex linked recessive factor. However Brown and Robinette (1967) found that their data did not support this hypothesis and concluded that the trait was not a simple sex linked Mendelian recessive. Both Brown and Robinette (1967) and Brown and co-workers (1968) note that the distribution of smell threshold for KCN is trimodal when a serial dilution of KCN is used. It was decided not to include this trait in the survey because of the possible hazard of transporting the cyanide solutions around schools. Since it had already been decided to include PTC tasting in the survey it was not considered safe to carry toxic solutions in the same kit of equipment as solutions to be tasted, in case of spillage.

In preliminary trials some tests were made on the smell properties of n-butyl mercapton. Patterson and Lauder (1948) had reported that some persons were unable to smell this substance, but the proportion of non-smellers was very small. The trials for the current survey showed that this test could not be made acceptable for use outside research laboratories, as the dominant scent of n-butyl mercaptan is that of skunk.

A difference in ability to smell verbena was noted by Blakeslee and Salmon (1931). They established that two thirds of the population found the red verbena to be scented, but not the pink, while the remaining third could smell the pink but not the red. Though this is an interesting polymorphism it was not possible to include it in the present survey owing to the difficulty of maintaining a supply of flowers for the test. It also seems likely that there are rare instances of hereditary absence of olfaction. Lygonis (1969) noted a family of 52 Farne islanders of whom half were unable to detect any odour from amyl acetate, benzine, clove oil, peppermint oil or ammonia.

2E.3 Ear Variations

The most commonly studied ear type variation is the degree of adherence of the ear lobe. This trait was included in the main survey. A further ear polymorphism which has been the subject of recent survey work is the presence of hairs on the ears. However the major part of this work has been carried out in Asian, Israeli, Aboriginal or Japanese populations. (Gates et al 1962, Stern et al 1964, Basu 1965, Chattopadhyay 1966 ab, Slatis and Apelbaum 1963, Abbie and Ras 1965, Stern and Tokunaga 1965). It is uncertain whether this trait appears with any appreciable frequency in European populations. Slatis (1964) found that only 11% of a sample of American white males under 39 showed this character.

Many authors have suggested that ear hair may be determined by a factor of the Y chromosome. Some pedigree data supports this view (Gates et al 1962) but other workers do not agree with this hypothesis (Stern et al 1964). However it has been established that in general the trait does not appear in females, though Sarkar and Ghosh (1963) noted its occurrence in Bengalese girls at a Deaf and Dumb school. The frequency of ear hair in the populations studied increases with age (Chattopadhyay 1966a, Stern et al 1964). Basu (1965) found that there were no males with this trait under the age of 20, while Slatis and Apelbaum (1963) found that only 1.1% of those between the ages of 18 and 29 showed this trait. In this case it seemed that there were two major objections to the inclusion of ear hair as a survey variable. The frequency of the trait in the country was uncertain, but even if the trait did occur the age range of the sample would have excluded the possibility of detecting the trait.

Another interesting ear variation was reported by Linder (1948) who suggested that the ability to move the ears was inherited. However it was not thought practicable to include this trait in the survey owing to the practice factor in the ability, and to the difficulty of demonstrating the required movement.

Variations in ear shape include the presence of the Darwinian point of the pinna (Winchester 1964) which is comparatively rare. Small pits are sometimes found on the side of the head just anterior to the ear. These pits may represent an opening to the upper anterior end of the helix. The hereditary nature of the ear pit trait has been confirmed by the pedigree studies of Whitney (1939), Cannon (1941), McDonough (1941) and Pipkin and Pipkin (1943). However the penetrance of the trait is low, most affected subjects showing ear pits on only one side. McDonough reports a pedigree of ear pits including discordant monozygotic twins. However the son of the unaffected twin was found to have ear pits.

It has also been noted (Matsunaga 1962) that ear wax type is polymorphic, being either soft and sticky or hard and brittle. The trait has been extensively studied in Japan, where the majority of the population are of the hard ear wax type. But in European groups the majority have soft ear wax. Matsunaga (1962) reports a survey of a German population where only 3.1% showed this trait. It was decided not to include ear wax type in the survey owing to the difficulty of obtaining and handling the samples of ear wax. Kalmus et al (1964) have suggested that a small wire loop is used to extract the wax, specimens then being stuck to index cards by sellotape. This type of activity was known to cause some embarrassment among the subjects.

2E.4 Variations in Hand and Foot

In the present survey the relative lengths of the second and fourth fingers was noted, but a number of other hand variations were not examined. One of the most widely known of these is the 'hitch-hiker's' thumb. In this condition the distal thumb joint shows hyperextensibility, it being possible to bend the joint backwards at least 50°. The difference may be skeletal (Glass and Kistler 1953) and it is not affected by age or sex. Glass et al (1952) found that 24.7% of the white US population showed this characteristic in comparison with 16.8% of a religious isolate. A further study by Glass (1956) showed the proportion of 'hitch hiker's' thumb in an isolate to vary between 11.4% and 15%) according to the generation. However Wheatcroft (1967) found that only 6.1% of a sample of British students could be classified as possessing a 'hitch hiker's' thumb. This low frequency of the trait meant that there would be difficulty in obtaining statistically significant results without a very large sample size. It was also found in a preliminary trial that it was comparatively difficult to explain the trait to those subjects who had not encountered anyone with a 'hitch hiker's' thumb. Some possibility of a learning effect was also noted as those most anxious to demonstrate the hyperextensibility were able to produce a larger angle of bending of the joint than those who had not been aware of their ability.

In the 'hitch hiker's' thumb trait the hyperflexibility appears to be confined to a single joint. However Sturkie (1941) noted that hyperflexibility of a large number of joints (particularly of the hand) was inherited. This type of hypermobility can give the ability to reverse the proximal joints of the thumb, a trick sometimes illustrated in text books of genetics. Wheatcroft (1967) used this second thumb ability in her survey of a British student group and found that 8.5% could demonstrate this ability. There was again some difficulty in explaining what was required, and the learning element was probably also present.

Reports of rare finger abnormalities, such as the triphalangeal thumb pedigree noted by Swanson and Brown (1962) cannot be considered for a survey of this nature. Similarly, comparatively rare polymorphic traits could not be used. One trait which fell into this latter category was the inherited radial curvature of the little finger (5th digit). In this hand variation the 5th and sometimes the 2nd finger have their top joints bent radially though this curvature is not sufficient to impair normal functioning (Glass and Magee, 1935, Stiles and Schalk 1945, Dutta 1965). It was decided that this trait was not sufficiently widespread to be of use in the present survey.

A further trait involving the relative lengths of fingers was used by Glass (1956) in his study of the religious isolate. He classified hand types according to the length of the fifth digit in relation to the fourth digit. It seems possible that this variation represents a different method of recording the second/fourth finger variation that was used in the survey. It was decided to use the second/fourth finger polymorphism rather than the fourth/fifth polymorphism because the former variation was more widely used in research projects. However in retrospect it is realised it would have been advantageous to include both variables, as this would have established whether they represent the same basic difference in hand pattern.

Similar surveys of relative toe length were conducted by

Kaplan (1963, 1964). He suggests that there is a single locus responsible for producing a long hallux (1964), and also proposes that the pattern of relative length of the first three toes may be inherited (1963). The investigation of toe lengths would have involved the children removing their socks, though it would have been possible to assess this through stockings. Since there was some resistance to removing shoes for the purpose of measuring foot length it was felt that further investigation would lead to refusals. Another toe variable noted by Venning (1956) involved the number of phalanges in the 5th toe. This can be either two or three, but in order to determine this with accuracy it is necessary to x-ray the foot.

2E.5 Hand Clasping and Arm Folding

When subjects are asked to clasp their hands together with fingers interlocked it is possible to classify them into two groups according to their thumb position. Some persons habitually interlock their hands so that the right thumb is over the left, while in others the situation is reversed. Similarly arm folding gives rise to two groups; those who fold right over left and those who fold left over right.

Various authors have considered the frequency of the hand clasping types in different ethnic groups (Freire-Maia et al 1958, Pons 1961, Lai and Walsh 1965, Freire-Maia and Almeida 1966, Tiwari and Bhasin 1969). Most of the frequencies of right hand clasp type are in the range of 50% to 60%. Arm folding has received less attention, but Freire-Maia and Almeida (1966) quote various populations where the frequencies of right dominant arm fold range from 40.5% to 44.0% . The exception to this pattern is a small Russian sample, where 91.23% were right arm folders. This difference is probably cultural.

Though the high frequency of occurrence of these variations would seem to make hand clasping and arm folding suitable for use in the present survey it was decided that they could not be used owing to uncertainty about their genetic status. Lutz (1908) found that there was no simple Mendelian explanation for the family data on hand clasping, though the children of right hand clasp parents were more likely to be right handed in this trait than left handed. Wiener (1932) found no evidence of the two traits being inherited or associated with laterality, and concluded that the differences probably resulted from habits formed in early life. This view was also taken by Lai and Walsh (1965), who found that the hand clasp types of offspring were distributed at random in the parental hand clasp types. Freire-Maia and co-workers (1958) suggest that there may be parental influence possibly including prenatal factors. Hand clasp and arm fold were not found to be significantly associated with each other or with laterality in writing in a study of British students (Wheatcroft 1967).

2E.6 Variations in Tongue

Most reported tongue variations concern the ability to perform various unusual activities with the tongue. The most common of these is tongue rolling. In this the sides of the tongue are rolled upwards inside the mouth to give a tube effect. This ability is said by Winchester (1964) to be inherited as a dominant Mendelic factor. However Scheinfeld (1965) notes that MZ twins may show discordance for this trait. Kloepfer (1946) carried out a large scale family survey, classifying three grades of ability in tongue rolling. He found that some subjects who were unable to roll their tongue at a first interview were later taught the ability by other members of their families. From this it must be concluded that the ability to roll the tongue is subject to strong environmental pressures and teaching effects. It was decided not to include the trait in the survey for this reason, though the high frequency of positive cases would have made the potential variation easy to study. Scheinfeld (1965) reported that about two thirds of the population had this ability, and this was confirmed by Wheatcroft (1967) who found that 61% of a British group were tongue rollers. This is also in agreement with Liu and Hsu (1949) who found that 62.2% of a Chinese population could roll their tongues.

Another similar tongue variation is of rare occurrence. This trait involves the ability to fold the tip of the tongue back against the main part of the tongue, without using the teeth or roof of the mouth. Whitney (1949) found the trait present in 1.4% of Americans, while Liu and Hsu (1949) noted a frequency of 5.2% in China. Hsu (1948) quotes pedigree data which indicates that the trait is probably determined by recessive factors. A further rare tongue ability was noted by Hoch (1949) who found three persons in the USA who were able to change the shape of their tongues to form a 'clover leaf' shape. These traits were considered to be too rare to be usefully included in the present survey. There was also the difficulty of demonstrating the required tongue position.

Spuhler (1950) suggested that pattern differences in the vallate papillae of the tongue could be used as an anthropological variable. In his study of Navaho Indians he counted the number of papillae and found that they could be classified as forming V, Y and W shapes. However in order to investigate this trait it is necessary to pull the tongue of the subject forward before counting the papillae which are 1mm in length and diameter. In practice this is far from easy, and it was felt that attempts would be resented by the subjects, so it was decided to abandon further investigations of this trait.

2E.7 Variations in Hair Patterns

Setty (1961, 1962, 1964, 1966ab, 1969), has contributed many studies in the variations of pattern in the body hair of white American males, and Slatis (1964) has noted the association of body hair and baldness. Both Baldness and body hair patterns would be useful characteristics for study in a mature sample, but the present survey was confined to the age range 14-15, so neither of these traits could be used.

The directional patterns of the down hairs of the forehead were studied by Kiil (1948ab). He was able to classify his subjects into three pattern types, and found that MZ twins were concordant for the character. One of the pattern types was not present in a group of Mongols.

Though preliminary trials were carried out to test the suitability of this trait it proved too difficult to classify the hair pattern types, so it was decided to abandon this trait. Catatrichy was a hair condition that was not included in the survey because of its low frequency. In this inherited condition there is an area of hair at the front of the head that falls out when it reaches about five inches in length (Stoddard 1939).

2E.8 Facial Variations

In an ideal study one would wish to include variations in the face as a whole in addition to the simpler single organ differences. But such a study includes the use either of extensive anthropological measurements or photographic records. The former technique was used by Brues (1946), who showed that there were differences correlated with national extraction within the American population. Brothwell and Harvey (1965) made many measurements and photographs of the inhabitants of Tristan da Cunha, and noted the value of this procedure.

In a more complex approach Lu (1965) devised 3 cycled Fourier equations to represent the frontal and lateral aspects of the human face. Unfortunately the time available for interviewing each subject in the present survey was limited, and so it was not possible to undertake a detailed programme of facial measurements. Nor was standardised photographic equipment available at the time the survey began.

Further variations which have been noted by Post (1969ab) are only dianosable from skull specimens. Post has noted population differences in nasal septa and in tear duct channels and he correlated these differences with selective pressures. It might be possible to devise some method of investigating these variables in the living subject, but such methods would need clinical abilities.

2E.9 Blood Group Systems

The blood group systems are well known to have a very high level of heritability, and so they would seem ideally suited to use in surveys such as the present study. However in practice the situation is complicated by the need to obtain a blood sample, and then by the problem of blood-typing the specimen. A finger prick will give sufficient blood to use for immediate testing with anti-A and anti-B, or Eldon cards, but further investigation needs a sample of venous blood. This means that a qualified person much be available to take the blood, and that consent for the sample to be taken must be obtained from the subjects' parents where minors are being used. There is also some loss of volunteers when blood samples are required.

Having obtained the blood ssmples it is necessary to send them to a blood grouping centre for typing, as the blood group antisera are only available at these establishments. This requires the consent and cooperation of the staff of the establishment, and as these workers are usually under pressure it is often impossible for them to undertake large scale surveys. It will be seen (Section 4B.7) that in the present twin survey some difficulty was experienced in finding an establishment willing to blood type 58 twin pairs. If blood typing of 700 specimens had been required it is unlikely that any cooperation would have been obtained.

Even using the finger prick technique the ABO system alone would have required large amounts of antisera. The alternative would have been to use Eldon cards which also allow for testing for the D factor of the Rhesus system in addition to the ABO systems. However the cost of the necessary Eldon cards was prohibitive. Another factor in the use of blood typing is that of time. Extracting the sample from the subject would take a variable length of time, and with comparatively small samples it would be necessary to test them as soon as possible.

It is notable that the major part of blood group work comes from workers who use the National Blood Transfusion Service data, or from hospital records. Dawson (1964) used BTS data in a study of occupational groups and blood groups, as did Roberts (1942), Mourant and Morgan Watkin (1952), Morgan Watkin (1965) and Hatt and Parsons (1965) in their anthropologically based surveys. In the present project it was hoped to look at blood group frequencies in social class groups, using BTS data, but this aspect of the project was abandoned owing to lack of time. Though it was impossible to use direct blood grouping in the main survey it was hoped to obtain the ABO blood group of the secretors of the sample by testing their saliva. Unfortunately it was not possible to obtain sufficient saliva, and so no blood types could be undertaken.

2E.10 Biochemical Variations

One polymorphic trait often used in class demonstration is the variation in the excretion of red pigment in the urine after consumption of beetroot. Allison and McWhirter (1956) suggested that the factor producing pigment excretion is probably a simple Mendelian recessive and Saldanha (1962) confirms this. Saldanha (1960) also found that pH affected the pigment, and that there was no sex difference in its expression. However the application of this trait in a large scale survey would present difficulties, as it is necessary to obtain cooked beetroot, weigh this into portions and supervise its consumption by the subjects. Then, three to four hours later it is necessary to collect urine samples from the subjects. This sequence of activities would not be compatible with a survey undertaken during school time. The same disqualification would apply to excretion of methyl-mercaptan after consumption of asparagus, which was also reported by Allison and

McWhirter.

A naturally occurring variant that might be used in general surveys is the excretion of beta-amino-isobutyric acid (BAIB) in the urine. Harris (1953) noted that 9.6% of a British group were high excretors of BAIB, and Calchi-Novati and co-workers (1953) suggested that high excretion might be due to a recessive factor. Further study would have involved collection of urine samples and chromotographic analysis of these samples, possible using the methods of Berry and co-workers (1955) and Gartler and co-workers (1955). However it was decided that in view of the adverse reaction of subjects when asked to provide a saliva sample it would not be advisable to ask for urine samples. This might have caused excessive embarrassment to the subjects as much of the survey was done in laboratory prep rooms or at the back of the main class, and the disruption of the class by children visiting the lavatory would not have been appreciated by staff.

2E.11 Anatomical Variants

Montague (1947) describes a condition in which the palmaris longis muscle of the forearm is missing. He ascribes this deficiency to the effect of a single gene which acts to inhibit the muscle's development. The presence or absence of the muscle can be diagnosed in the living subject, though postmortem data gives a clearer picture. A similar deficiency is found in the leg, where the petroneus tertius muscle is sometimes lacking. (Spuhler 1950).

It was not felt that these traits could be included in the survey owing to the anatomical inexperience of the interviewer.

A further variation suggested for investigation by Spuhler (1950) is the pattern of the superficial veins of the anterior thorax. There are two pattern types, transverse and longitudinal, and Spuhler records that seven pairs of twins were concordant for this variation. Unfortunately it is necessary to record the vein pattern by infra-red photography before classification, and this made it impossible to use the variable in the present survey.

2E.12 Dermatoglyphics

Dermatoglyphics have been the subject of extensive studies since the work of Bonnevie (1924). It is now comparatively easy to take finger and palm prints using the new non-inked systems which employ chemical developer and sensitised paper. These new developments have simplified the basic technique, but there are still many factors involved in producing useful prints.

There were two potential associations of dermatoglyphics that could usefully have been investigated in the present survey. It has been noted by previous authors that lateral dominance and dermatoglyphics show an association (Cummins et al 1931, Newman 1934, Cummins 1940, Cromwell & Rife 1942, Holt 1953, Rife 1955). This could have been further investigated. In addition there has been a report that schizophrenia shows an association with ridge count

(Möller 1967). Though this has been challenged by Singh (1967) it would have been interesting to examine the possible relationship between social class and fingerprints, as a fall in social class has been shown to be associated with schizophrenia.

Preliminary trials showed that it was not easy to obtain usable finger and palm prints, and the process was very time consuming. It was felt that dermatoglyphics could not be combined with the other variables of the survey because of this time factor. It was not possible to gauge the amount of time needed per child as there was great variation in the ease with which hands could be printed. This would have complicated the organization of the survey to an extreme degree, and so it was decided that dermatoglyphics should not be used.

2E.13 Skin Colour

Human skin colour shows great variation even within menbers of one racial group. Ainsworth Harrison and Owen (1964) studied the skin colour of mixed African/European hybrids in Liverpool, and Sunderland (1967) investigated skin colour in Eastern Jordan. In both cases the apparatus used was an EEL portable reflectance spectrophotometer. Such a machine was available at the University of Aston and it would have been used in the present survey. This idea was not put into practice, the reasons for its rejection being in part the time consuming nature of the testing and the size of the apparatus. The deciding factor against an investigation of skin colour in Birmingham was the potential problem of racial tension. Though race relations in the city are good it was felt that an investigation of skin colour might be misinterpreted by the subjects.

2F - Introduction to the Methods Used for Determining the Survey Traits

It is now proposed to discuss the methods used for each of the traits included in the survey, with a full account of methods used by previous workers. Reports concerning the inheritance of the traits in question will also be discussed in each section, as these were considered during the choice of traits to be included in the survey. A list of suppliers of certain pieces of apparatus has been included in the appendix (table A10).

2G - Eye Colour

2G.1 Physical Basis of Eye Colour

The term 'eye colour' in fact refers to differences of iris colour, since the colour of the sclera and the apparent colour of the pupil are constant. The appearance of the iris is determined by its structure and pigmentation. In most mammals the iris is made up of three layers, but in man the outermost layer is lost (Carter 1962). The outer of the two remaining layers, the stroma, is formed from muscle and connective tissue, while the inner layer is epithelial. If the inner alone is pigmented the eye appears light-coloured, usually either blue or grey. If there is pigment in both layers the eye appears dark, either brown or a mixture of colours (Davenport 1927). Davenport (1927) suggests that red haired persons have yellow pigment in addition to the dark melanitic pigment. This gives a green effect in eyes that would otherwise be blue, and produces a warm reddish brown in dark eyes.

2G.2 Genetic Determination of Eye Colour

In general the factors producing dark eyes are dominant over those producing light eyes (Davenport 1927, Scheinfeld 1966). However there is considerable variability of the actual colour and appearance of the iris in the human population, and it seems unlikely that eye colour is determined by any very simple genetic system. Brues (1946) has suggested that there are six genetic factors responsible for eye colour. She proposes that the factors for the colour and the pattern of relative smoothness of the iris are inherited separately, though their visual effects are inter-related. Brues first factor mediates for heavy pigmentation if the iris is smooth, and her second factor determines whether the pigment in a smooth iris is brown or mixed in colour. She proposes two sex linked dominant factors, one producing non-light eyes and one affecting the iris pattern. Her fifth factor would change the pigmented areas of a mixed eye from yellow to brown, and the last factor gives the rare effect of dark non-smooth eyes. In 1950, Brues noted the association of sex and eye colour again.

It has been suggested that the colour of the iris rim may differ from the rest of the iris. However Bernstein & Berks

(1948) found that 78.6% of their sample had iris rims of the same colour as the main part. Davenport (1927) in a review of previous survey work, noted that some workers had found a sex difference, in that there was an excess of blue-eyed males. This result would be expected if Brues' theory was correct, however Davenport's reports refer to the British Isles whereas Brues' subjects were American.

2G.3 Nominal Classification of Eye Colour

The most common method of determining eye colour in survey work is simply for the observer to inspect the eye and classify it according to some nominal scale. This method was used by Hooton & Dupertuis (1955) in their anthropological study of Ireland. In their investigation eye colour was classified as pure brown, green-brown, grey-brown, blue-brown, grey plus grey-blue or blue. Kloepfer (1947), MacConnaill (1942), Sewall (1939) and Davenport (1927) merely classified eyes as light or dark. Riddell (1941) quotes Tochers classification which gives four groups; pure blue, light blue and grey, mixed colours and brown or hazel homogenous at two feet away. Riddell himself suggests a more complex system in which eye colour is coded as a three digit number, the first figure giving the main colour of the iris, the second figure representing any diffuse colour present and the last figure signifying the presence of spots of another colour. The six colours proposed by Riddell are coded as follows: 1) blue, 2) grey, 3) green, 4) yellow, 5) tan, and 6) chocolate. Thus an eye coded as 120 would be mainly blue with some grey colour but no pigment spots.

2G.4 Comparative Classification of Eye Colour

The classification of eye colour by a nominal scale must of necessity be somewhat subjective. Many workers have used standard scales for comparison with the subject's eye in order to reduce this source of error. In a study of phenylketonuric children, Berg & Stern (1958) used the Martin scale of glass eyes, but this scale is not easily available in Britain. The Munsell Colour Company produce standard paper colour charts which can be used for characterising eye colours. However these plain paper slips are most unlike the majority of eye colours as in the eye the overall impression of colour is made up from heterogenous streaks and patterns of different colours.

Even when a standard scale is obtained there may still be difficulties. Grieve & Mourant (1947) found that paper scales faded and that plastic and glass eyes tended to vary from set to set. They also found two observers might classify the same person differently even when using the same set of artificial eyes for comparison. It seems that the use of a comparative scale of some sort in the classification of eye colour can reduce intra-observer variation, but it cannot eliminate variation between observers.

2G.5 Artificial Eye Colour-Scale

In spite of the limitations of the standard scale method it was decided to obtain a standard range of artificial eyes for use in the survey. All of the artificial eye makers whose addresses could be found were contacted; a total of seven firms. These were all most helpful, one offering photographs of his patients, or a selection of a hundred glass eyes to pick those that would be most useful in the survey. Only one of the firms produced a standard colour range for use by the prescribing optician. This was the largest firm, Art Eye Ltd., whose artificial eyes are not glass but plastic. Instead of producing a standard range of whole eyes, Art Eye have a standard range of 72 iris buttons (they also produce a range of 72 sclera but these were not required in the present survey).

Each iris button is a 11mm diameter disc of clear plastic, flat on one side and convex on the other, reaching a depth of 3mm at its central point. The flat side of the button is painted with a black disc 3mm in diameter in the centre to represent the pupil. This remaining circular portion of the iris button is painted to represent the iris, various combinations of colours and patterns being used. The effect of this painted iris when viewed from the convex surface is most life-like. In fact many of the children interviewed became somewhat apprehensive when they saw the eye colour scale, believing the iris buttons to be real eyes.

The iris buttons are presented by the manufacturers in a case which contains a white plastic plate with rows of numbered indentations. Each iris button is numbered on its underside and rests in the appropriate indentation without any permanent attachment. This arrangement is presumably to facilitate the removal of a single iris button for matching in a clinical situation.

It was originally hoped to match eye colours in the survey by taking out a single iris button, placing it in a neutral artificial sclera and comparing it with the eyes of the subject. However it was found that this procedure tended to be time consuming and there was also a danger of mislaying or losing the iris buttons. It was therefore decided to saw up the original white background to give strips of indented white plastic, and then stick the eyes into the indentations using a removable fixative (Cow gum). These strips each contained up to ten iris buttons, arranged in colour groups (see below). It was therefore possible to choose the appropriate strip and compare this with the eyes of the subject by removing the strip from the box and putting it in a vertical position to one side of the subject's face.

Since it was not possible to keep a tabulation of 72 different iris colours in the survey, it was decided to put the 72 buttons into groups. The buttons were inspected using the standard colour matching lamp, (see 2H.10), and it was found that twelve divisions could be made. These were: blue, blue-grey, grey, grey-green with brown centre, green-brown, grey-brown, light brown, mid-brown and dark brown. A number of trials were carried out in which the buttons were mixed up and then sorted out into the twelve groups using the standard colour lamp. It was found that the majority of the iris buttons were classified as the same colour in six successive trials. When there was any variation in classification it was either between the shades of pure brown or between grey-green and green. Even when this variation did occur it was still possible to decide in which group the button should be included, as all the variable cases showed a clear majority of classification into one of their two possible groups. In the statistical examination of the eye colour data it was found that all twelve colour groups could not be used singly, owing to the low totals in some. They were therefore combined to give three main colour divisions; light (blue or blue-grey), mixed (grey, or green, or grey-green, or grey-green with brown centre), and dark (green-brown, or grey-brown, or light brown, or mid-brown, or dark brown).

Trials were carried out to check whether the 72 colours were enough to cover the range of human eye colour likely to be met in the survey. Forty subjects were used, mainly students and staff of the University. Each person's eye colour was classified on three occasions by the same observer, using the colour matching lamp. Both the number of the iris button and the colour groups were noted. In fact 95% of the subjects were given the same classification by number of all three occasions, the others obtaining the same number of two of the trials. All the subjects were placed in the same colour group in all three trials. It was therefore concluded that this iris matching set could be used as a standard in the main survey. It was noted that there were a few persons with very pale homogenous blue eyes whose equivalent could not be found in the original range. Art Eye were contacted, and they agreed that there was a fairly common pale blue eye that was not included in the range but which was often added to the range by their customers. This iris button was therefore purchased and added to the original 72 iris buttons. This supplemented range of iris colours was used in the pilot survey and it was then possible to classify all the subjects' eye colours with ease. This method was therefore carried on to the main survey.

2H - Colour Vision Defects

2H.1 History of Colour Vision Defects

Though some authorities attribute the discovery of differences in colour vision to Plato (Kalmus 1965) the defect only gained general recognition following its investigation by Dalton in 1798 (Kalmus 1965). Dalton himself had defective colour vision. Since that time it has been established that there are various forms of colour defect, some hereditary and some acquired. Of the hereditary defects the most common are the red green colour defects.

The system of definition of colour vision defects can be considered to refer to three main colour stimuli, red, blue and green. In normal vision combinations these three colours are required to match all shades perceived. Those who require the three main colour stimuli in the average proportions are known as trichromats. However a small proportion of the population require three colours for colour matching but the relative intensities of the colours in their matching tests differ from the normal population. Such people are known as anomalous trichromats. If more red stimulation is necessary the patient is said to be protanomalous, if more green stimulation he is deuteranomalous and if the blue perception is deficient he is said to be tritanomalous.

Dichromats are able to match any colour by means of only two of the main colour stimuli. This is the more severe form of colour defect. Persons with this grade of defect are called protanopes, deuteranopes and tritanopes respectively. In discussing the types of defect without specifying the grade it is usual to speak of deutan, protan and tritan defects. (Kalmus 1965). In the protan defect red and blue-green are confused, and in the deutan defect the confused colours are red-purple and green (Hardy et al 1964).

2H.2 Heredity of Colour Vision Defects

Both protan and deutan defects are sex linked, the genes responsible being located on the X chromosome. This means that the incidence of red/green colour vision defects is much higher in males than in females. Most workers hold the view that there are two loci, one responsible for deutan defects and one for protan defects (Pickford 1964). In order to account for the variation in the degree of defect it is necessary to postulate a series of alleles at each locus. At least three alleles would be necessary in order to give rise to normal colour vision, anomalous trichromats and dichromats (Wald 1966). It has also been suggested that there may be two loci responsible for protan defects. Wald (1966) also thought that tritan defects were due to a rare autosomal gene.

2H.3 Physiology of Colour Vision Defects

The nature of the defects in protan and deutan subjects has not yet been fully elucidated. Walls (1955) suggests that the human retina contains three kinds of cones, and that the visual defects are due to deficient neural pathways. Dvorine (1965) says that defects could be due to abnormal development of either the retinal receptors, the optic nerves or the neural pathways between the retina and the cerebral cortex. However Wald (1966) thought that the defects could be due to lack or deficiency of one of the visual pigments.

2H.4 Methods of Testing Colour Vision

There are three main methods of investigating colour vision defects: the anomaloscope, sorting tests and pseudoisochromatic plates Lakowski (1969b) has suggested that the most reliable results are obtained by using a battery of tests including all three methods. He also suggests that the anomaloscope comes closest to testing pure colour sensation, and notes that pseudoisochromatic plates give a complex colour stimulus. Vics (1966) found that different results were obtained when various tests were carried out on the same children, and Sweeney and co-workers (1964) found differences between the diagnoses from pseudoisochromatic plates and the anomaloscope method. In general the method used tends to be determined by the time and apparatus available to the investigator.

Anomaloscope Testing

The anomaloscope is an instrument designed to measure the colour matching ability of the subject. In investigating red/green defects the subject is asked to observe a small illuminated field. This field is divided in half, one half being fixed yellow light and the other being variable in colour by the subject. The subject is asked to match the yellow half of the field by means of a mixture of red and green light. For any particular shade of yellow the proportions of red and green required to provide a match are fairly constant in normal trichromats. In those with protan or deutan defects the 'match' for the yellow is found to be different from the average match (Kalmus 1965). The anomaloscopes available commercially tend to be both bulky and expensive, but Pickford and Lakowski (1960) have described a machine that could be built in a laboratory workshop. Other areas of colour vision than the red/green differences can be explored by using different colour filters in this anomaloscope.

Though anomaloscope testing may be the best measurement of visual sensation (Lakowski 1969), such testing requires more time and facilities than other types of test. Schmidt (1955) has shown it was necessary to allow a neutral adaptation period for the subjects before and between making colour matches. He also found a considerable learning effect which meant that the first two results of a series must be rejected. The lighting and circumstances of the test are also very important.

2H.6 Sorting Tests

These vary in complexity from the simple naming of colours as in coloured wool tests, to the complex Munsell 100 Hue Test (Kalmus 1965). Children have been tested with toy bricks, balloons and standard colour charts to see if they could name colours correctly (Vics 1966). In the Munsell 100 Hue Test the subject is presented with 85 coloured discs which are related to each other to form a closed circle of colours. The subject is asked to arrange the discs in their natural sequence by colour. This test is said to be very time-consuming (Kalmus 1965) but it enables the whole field of colour perception to be examined.

2H.7 Pseudoisochromatic Plates

The third type of test involves the use of pseudoisochromatic plates. A number of these plates are usually combined in book form. Each plate has a neutral background, usually broken up into an all-over pattern of dots of varying size and brightness. Figures or shapes are formed by the replacement of certain areas of neutral dots by dots in the confusion colours that will not be distinguishable by colour defectives. In some tests the coloured dots are so arranged that those with normal sight read one figure while those with defective colour vision see another figure not easily recognised by the normal group. Although there are many different versions of the pseudoisochromatic test, two of these, the Ishihara test and the HRR test, are most commonly used. Since both these tests were available for us in the present survey it was necessary to decide which test should be used. Ideally it would have been of interest to use both tests and compare their results, however time did not allow this.

2H.8 The Ishihara Test

The Ishihara test was used almost exclusively prior to the Second World War, and this test is still used extensively. (Ishihara 1964). This set of pseudoisochromatic plates contains seventeen numerical plates. Of these one is a control plate, showing a number visible to both normal and defective colour vision, two contain numbers visible only to defectives and the remainder each have one or two digits which may appear unrecognisable or altered to colour defectives. A further seven plates show 'mazes' to be traced by illiterates or young children. The colour of the background dots varies, the plates having green, orange or grey as their basis.

The Ishihara test is designed to be administered either in daylight or in electric light adjusted to resemble daylight. The plates are shown to the subject at a recommended distance of 75cm, and at such a slope that the plane of the plate is at right angles to the line of vision. In the case of a subject who is able to recognise and name numerals, the seventeen numerical plates are then shown. Each plate is exposed for not more than three seconds, and the subject's reading of the number is noted. The subject's answers are then checked against a key, and a diagnosis is made. It is possible to diagnose the subjects as being normal or having protan or deutan defects by use of this test. However in the case of large scale surveys it is suggested by the Ishihara handbook that it might be possible to use only six of the plates (including the control) as a simplified test. This curtailed test might not be adequate for the diagnosis of the type of colour vision defect.

In tests using the whole range of numerical plates, the Ishihara manual suggests that subjects should be considered to have colour vision defects if nine or less plates are correctly read. One of the main problems of the Ishihara test is that a large number of colour normal subjects make mistakes in reading the plates. Belcher et al (1958) found that 46% of normal subjects made between one and six errors in the test. Two plates in particular (fourteen and fifteen) gave so many errors in normals that a theory was produced by Dronamraju (1963) to explain this as a x-linked characteristic. However Krill et al (1966) concluded that this effect was probably due to a fault in the test. They also found that a number of subjects who were diagnosed as normal by anomaloscope, were classified as defective by the Ishihara plates, obtaining twelve or more errors. It has been suggested that subjects showing errors in six to fifteen plates should be classified as having mild defects and those with more errors as definitely defective (Cole 1963). In all the situation regarding the permissible level of errors in the Ishihara test in a normal subject is far from clear.

2H.9 The Hardy-Rand-Rittler (HRR) Tests

The Ishihara plates have always been manufactured in Japan and it was realised during the Second World War that it would be advisable to set up another source of pseudoisochromatic plates. A team was set up to devise an American version of the test. The resulting set of plates, produced by the American Optical Company, are now widely used. They are commonly called the HRR plates, from the names of the team who produced them; Harvey, Rand and Rittler.

The HRR plates all have a neutral background of grey dots, and instead of figures the confusion colours occur in three shapes, a ring, a cross and a hollow triangle. The HRR set of plates consists of four control plates, six screening plates (including two for diagnosis of blue/yellow colour vision defects) a series of ten plates for further diagnosis of red/green defects, and a further four plates for blue/yellow defects. Each plate (except one control) shows one or two of the three shapes. Where there are two shapes in the red/green plates, one is coloured to be confused by protans and one by deutans, so that it is possible to differentiate between the two types of defect. The diagnostic plates for both red/green and blue/yellow colour vision defects are arranged in a graded series of increasing saturation (increasing visual difference from grey).

When the test is being used the subject views the plates at a distance of approximately 30 inches. The interviewer turns the pages allowing two or three seconds viewing of each page. The subject is asked to state how many symbols he sees, name and symbols and point to the symbol. In most cases it is only necessary to use the first four control plates and the six screening plates, those who give correct responses to the screening tests being classified as having normal colour vision. When errors occur in the screening test the subject is tested further using the more extensive diagnostic ranges of red/green or blue/yellow plates as appropriate. The grading of the diagnostic ranges by intensity enables a diagnosis to be made of the degree of the colour vision defect in addition to the division into protan or deutan defect.

The HRR test has been said to be 'possibly too neat' by one group of researchers (Belcher et al 1958). They also noted that none of the pseudoisochromatic plate tests that they investigated was without defect. Vics (1966) found that some children who gave false positive results with the Ishihara and other numerical plates were correctly diagnosed by the HRR plates. In an evaluation of the use of the HRR plates in testing servicemen, Seefelt (1964) found that only 1.7% of the subjects were mis-classified when the tests were used in a clinical interview situation. However when the tests were used with an 'assembly line' technique, 5.4% were misclassified. The originators of the plates claim 100% success for screening out colour defectives and a 97% success in classifying the defectives into types. They quote comparable figures of 98% classified for anomaloscope and only 74% for the Ishihara plates (Hardy et al 1954b). The same workers also claim that the test has good retest reliability, and that it takes less than three minutes to administer, so it would appear that they would expect the test to be used in the 'assembly line' situation (1954a).

The neatness of the HRR test, its swiftness of administration and ease of diagnosis made it preferable to the Ishihara tests in the present situation, where testing for colour vision defects was being included in a battery of other tests. The only disadvantage of the HRR test in the present survey is that it should only be administered using a standard illuminant. This should be Source C of the Commission Internationale de l'Eclairage, which has a colour temperature of 6700°K, and is an approximate representation of daylight. The HRR manual suggests that a Macbeth Easel lamp can be used to illuminate the plates, but it was found that these lamps were only available in America. Hardy (1945) gives the method of producing Source C from a gas filled lamp and two liquid filters but it was necessary to obtain portable equipment for the present survey.

2H.10 Standard Illuminant

It was discovered that there was a British Standard

(BS No 950 Part I 1967) concerning artificial daylight fittings for colour matching. This suggested a revised standard illuminant instead of Source C. This new standard is called Standard Illuminant D6500 and it has a colour temperature of 6500°K instead of 6700°K. It was decided that the HRR plates could be used with the new standard illuminant without loss of accuracy, and subsequently Phillips Electrical Ltd were contacted for advice. Phillips Ltd proved most helpful, and sent a representative of their lighting design department, Mr. Cruikshank, to discuss the problem. Mr. Cruikshank advised that a lamp should be built in the department, using two two-foot colour matching fluorescent tubes. However in practice it was found that this was not possible owing to technical difficulties.

It was then discovered that there was a lamp designed for technical drawing which would take eighteen inch fluorescent tubes. This lamp, the Linora Spotline Type SL 18/2, is extremely heavy, and rather difficult to transport as it measures at its extremities 19" by 19" even when fully folded. It is not designed as a portable lamp and should in fact be clamped into the working surface so as to obtain full benefit from the cantilever arm. However in spite of these difficulties this lamp with two Phillips 18" colour matching 55 fluorescent tubes provided a most useful standard illumination both for colour vision testing and for the eye and hair colour comparisons.

2H.11 Sex Differences in Colour Vision Defects

The incidence of colour vision defects in females is very low, about 0.04% (Pickford 1969). It was therefore decided to include only males in the testing for colour vision defects. If the females had been included it was expected that only one with colour vision defects would have been detected out of the total of 317. It seemed legitimate in this case to test only the male subjects.

2I - Ocular Defects

In order to undertake a full survey of ocular defects one would need either testing facilities (with appropriately qualified assistance), or, as in the work of Jevons (1957), access to medical records.

In the present survey it was not possible to test the subject's vision, nor could the school medical records be examined. However it was decided that useful, though limited, information might be obtained from the subjects' own reports of their ocular defects. The experience of the pilot survey showed that most subjects were vague as to the nature of their defects if any were present. It was therefore decided to score the subjects as wearing glasses (or contact lenses) all day, wearing glasses for certain activities only, or not needing to wear glasses. This classification is of course dependant on the honesty of the response, but there was no reason to suppose that the subjects would wish to mislead the interviewer on this point. In fact many subjects volunteered the information that they were supposed to wear glasses but had abandoned them for reasons of vanity or convenience.

2J - Hair Colour

2J.1 Anatomical Basis of Hair Colour

Human hair colour is determined by the presence of pigment granules within the keratin shell of the hair. Barnicot and co-workers (1955) studied cross section of hairs of different colours by electron microscope. They noted that the pigment granules in dark hair were apparently solid, whereas those in rather lighter hair had a less dense core. Light coloured hair contained smaller and rounder granules, and the pigment granules from red hair were not homogenous in shape.

Vernall (1963ab) studied the distribution of pigment granules in hairs of four races and found that there were both racial and individual differences. There are also colour differences between the individual hairs from the same person (Nicholls 1968). Age may also influence hair pigmentation. It has been noted that hair tends to darken with increasing age (Steggarda 1941, Trotter 1930), though eventually there is a loss of pigment in old age.

2J.2 Heredity of Hair Colour

Hanna (1953) found that MZ twins showed significantly more similarity in hair colour than DZ twins. Rostrand and Tetry

(1965) have suggested that the factors producing dark and red hair are dominant over those producing light hair. Hanna (1956) proposed that the continuous variation of human hair colour could be the result of the interaction of many genes.

The inheritance of red hair has been investigated by a number of workers. Reed (1962) confirmed that the trait was inherited but could not fit his family data to any simple Mendelian relationship. Other workers suggested that a single major gene determined the redness of the hair, but that there were also several modifiers (Singleton and Ellis (1964). Neel (1943) thought that the presence of red hair depended on a single incompletely recessive factor which was hypostatic to the factor producing dark hair. This red hair factor could occasionally show penetrance in the heterozygote. Scheinfeld (1965) noted that the effects of the factor for red hair may be masked by the basic melanin producing genes.

MacConaill (1942) suggested that there were developmental differences in pigmentation in the population of the British Isles. Dividing eye colour and hair colour into light and dark classes he suggests that, besides the four classes specified by this division, further factors affect the rate of development of pigment. These factors give rise to nine possible classes differing in developmental pattern, though the ultimate phenotypes may be equivalent.

2J.3 Methods of Classifying Hair Colour

Hair colour differences have been utilized in many anthropological surveys ranging from that of Fleure and James in 1916 to the microspectrophotometry of single hairs by Nicholls (1968). There are three main types of hair colour classification. Of these the most simple is the use of either a nominal scale or a standard reference range to classify the hair sample. A second method involves the investigation of the spectrophotometric properties of the subjects' hair. Thirdly attempts have been made to extract the pigment from hair samples.

2J.4 Use of Comparison Scale in Hair Colour Classification

Parsons (1920) suggests that most observers would divide the range of hair colours into five tints; fair, red, brown, dark brown and black. As previously noted MacConnail (1942) merely divided hair colour into light and dark classes. Trotter (1939) in a review article notes the difficulty of using a subjective classification of hair colours and quotes descriptive phrases used by many workers. She reports the use of the Fischer-Saller Hair Colour range. This colour range has been used extensively (Steggarda 1941, Hanna 1961). The original range was of artificial hair but this was later changed to real hair artificially coloured. Hanna (1961) used the Fischer-Saller artificial hair scale and notes that there are two series of colours, one ranging from grey to black and one from yellow to brown. Sunderland (1965) used the Fischer-Saller hair colour scale in a study of the hair colour of the population of Tristran da Cunha.

Other comparison methods involve the use of standard colour ranges other than hair or pseudo-hair samples. In 1930 Bellamy suggested the use of a colour wheel. The hair sample was to be placed in the centre of the wheel and an appropriate colour disc around the perimeter. When the wheel was rotated the textured effects of the hair were eliminated and it could be compared with a matt colour standard.

Though the use of the Lovibond tintometer may appear a sophisticated method of determining hair colour this is basically a simple comparison of the hair colour with colour standards. Trotter (1939) notes the use of a Lovibond instrument for this purpose as early as 1908. Another standard colour range is produced by the Munsell Colour Company. This company provide standard colour ranges for all purposes including the classification of hair colour.

2J.5 Extraction of Hair Pigment

Hanna (1953, 1956, 1961) has prepared a pigment solution from hair samples by refluxing the samples in 0.2N KOH. He prepares his samples by a lengthy process of de-fatting and drying. The presence of keratin in the pigment solution is allowed for by reading the optical density of the samples against a blank of hydrolysed keratin from fingernails. Only 50mg of hair was required to produce a sample, though Hanna used duplicate samples in all cases.

Lea (1954) suggested that hair pigment solutions could be prepared by refluxing the hair sample with urea in xylol for three hours. Water was then added to the sample and the optical denisty of the resultant solution was read. Only 10mg of hair was needed for this method.

A red pigment has been extracted from human hair by means of acid hydrolysis. Hair samples are refluxed in 0.1N HCI until no further pigment is extracted (Lee and Penrose 1947), or for up to ten days (Arnow 1938). Arnow suggested that the pigment thus extracted is the factor responsible for human red hair, and Flesch and Rothman (1945) found it was only present in red human hair. Barnicot (1952) tested samples of red hair from Africans for the presence of this red pigment which he called tricosiderin. He later suggested that while tricosiderin is extracted by acid, its precursor may be extracted by alkali. (1956a). However Barnicot also found that the tricosiderin pigment could be extracted from a whole range of hair colours, and that some red samples did not possess this pigment (1956b). Lee and Penrose (1947) found the pigment present in persons with grey or white hair and even in albinos.

All these methods were considered in the planning of the present survey. The advantages of a pigment extraction method are that a comparatively small hair sample is required, and that a suitable pigment solution can be diluted or concentrated at the convenience of the investigator. It is possible to measure the optical density of a solution with a high degree of accuracy.

However, when the methods quoted were discussed with biochemists within the department they advised against the use of any of these procedures. Their view was that all the methods were so crude as to open the possibility that by-products of the reactions of the hair sample and the solvent agent would give spurious results. Certainly these misgivings seem to be justified in the case of tricosiderin. Since the development of a new assay for hair pigment would be a research project in itself it was decided that it would not be possible to use any extraction technique for determining hair colour.

2J.6 Spectrophotometry of Hair Pigments

Though several workers have measured the optical densities of pigment extracts from hair it is uncertain whether differences in pigment extract represent differences in visual colour effect. In order to measure the visible colour of hair sample reflectance spectrophotonetry has been used. The earliest use of this method was by Gardner and MacAdam in 1934. They measured the percentage reflectance between 400 and 700mμ. There was a difference in the shape of the curves for red and brown hair in the blue and green bands. In general the non-red hair showed a straight line increase in reflectance from 400 to 700mμ whereas the red hair reflectance results followed a curve with the point of maximum curvature at 546mμ. The increased reflectance after this point is the result of reflectance from red pigment present in the hairs which is absent in the hair of non-red subjects. They recommend that one can discriminate between red and non-red hair sample by means of the ratio between the percentage reflectances at 546 and 700 mμ multiplied by 100. If this Gardner/MacAdam index is below 40 the specimen is taken to be a true red, if between 40 and 47 it is classified as red-brown, while those with hair indices over 47 are said to have non-red hair.

In 1952 Reed used spectrophotometric reflectance curves in an investigation of the inheritance of red hair. He took the percentage reflectance for wavelengths between 400 and 700 mμ, using a sample of hair to cover a circle 3cm in diameter. The hair was held between two pieces of cardboard. He suggested a redness index, the R index, as follows:

$$R = \frac{100(y_{530} - 0.243y_{400})}{y_{650}} \qquad y = \text{reflectance at the given wavelength.}$$

R values between 30 and 35 came from bright copper red hair, those from 36 - 40 were light red and those between 41 and 48 were red-brown. All those with larger R values were classified as non-red, but though this index was found to be in good agreement with eye judgement there was a 7% overlap between visually judged red and non-red in the classification by the R results. The hair in the samples was randomly arranged for the tests.

In studies of hair colour in phelylketonuria and the Fanconi syndrome Cowie and Penrose (1950) and Cowie (1956) used the E.E.L portable spectrophotometer. They recorded the percentage reflectance of hair samples at wavelengths between 400 and 700 mμ.

A hair sample was taken sufficient to cover a disc one and a quarter inches in diameter.

The most extensive study of hair colour reflectance is that of Sunderland (1955). In this survey 1000 hair samples from young men were examined. The hair samples were washed in dilute soap solution and mounted on pieces of black card with another black card covering the hair sample except for a 2.0cm diameter circle. The reflectance curves of the samples were measured by a Hardy Recording Spectrophotometer, at the National Physical Laboratory, and the readings were taken at ten wavelengths between 400 and 700 mμ. These values were converted to logarithmic equivalents for further calculation. The total of the ten untransformed values was taken as a measure of the total light reflectance of the sample. The shape of the reflectance curve gave an estimate of the colour of the hair sample. Sunderland (1955) noted that the curves for non-red hair were straight whereas the curves of the visually red hair samples were sigmoid shapes. However some light hair samples had curves that could be confused with the shape of the red samples. Both the R index and the Gardner-MacAdam index were used by Sunderland, who also calculated a discriminant function to differentiate between red and non-red hair.

2J.7 Present Survey Methods

It was decided to use the reflectance method of determining hair colour. Enquiries were made within the University about a suitable reflectance spectrophotometer, and it was found that the Physics Department possessed an E.E.L. spectrophotometer such as had been used by Cowie and Penrose (1950) and Cowie (1956). It was decided to carry out a trial investigation using this machine.

2J.8 Use of E.E.L. Spectrophotometer

The E.E.L. portable spectrophotometer has been used for hair colour studies as previously stated, and it has also been used in skin colour examination (Ainsworth Harrison and Owen 1964). The E.E.L. instrument is comparatively small as it is designed to be portable. The main body of the instrument contains the apparatus for registering light intensities, differences of which are shown on an external dial. A movable head is connected to this main body by means of a cable. In the head there is a light source which shines downwards at an angle of 45°. A 2cm diameter circular aperture in the base of the head permits the light to fall on the sample which is either placed under the head or has the head placed upon it according to size. The light reflected back from the sample is measured by a photocell inside the head, and this information is passed back to the main body of the spectrophotometer where it registers on the dial. A series of nine filters are fitted in the head of the machine such that any filter can be placed in the path of the light descending on the sample. The dominant wave lengths of these filters were 425 mμ, 465 mμ, 485 mμ, 515 mμ, 545 mμ, 575 mμ, 595 mμ, 655 mμ, and 685 mμ.

A total of 51 hair samples were collected from members of the department and students. These were washed in dilute Teepol, rinsed and dried. The samples were then arranged on cards such that the light would strike the majority of the hairs longitudinally. It had been realised that the orientation of the hairs might affect the reflectance results owing to the arrangement of the photocell and illumination. The correct placement of the hair sample in relation to the light aperture of the spectrophotometer head was achieved by means of attaching the hair sample in the appropriate position on a card of the same dimensions as the base of the head. When the card was aligned with the base, the hair sample was known to be aligned with the light aperture.

Each sample was tested twice at each of the nine wavelengths. The differing intensities of the filtered lights meant that it was necessary to adjust the reading of reflectance whenever a filter was changed. A standard block of chalk is used to give 100% reflectance. The surface of this block is freshly prepared by glasspaper sanding and then the head is placed directly upon the surface. The reading on the reflectance dial is then adjusted to 100. The total of the nine reflectance values was found in each case, and modified versions of the R index and Gardner-MacAdam index were calculated. It was unfortunately not possible to calculate these indices in their original form as only limited wavelength values were available. In the Gardner-MacAdam index 545 $m\mu$ was substituted for 546 $m\mu$, and 685 for 700 $m\mu$. But in the R index the substitution was less satisfactory. Instead of 400 mμ it was necessary to use 425 mμ , and for 530 mμ there was the possibility of using either 520 mμ or 550 mμ . Of these 520 mμ would on first sight appear the better choice, but in fact the point of inflection of the curve in red hair tends to be of a wavelength higher than 530 mμ rather than lower. However in these calculations 520 mμ was used as the substitute for 530 mμ .

2J.9 Difficulties of E.E.L. Spectrophotometer Use

The results of the preliminary trials with the E.E.L. spectrophotometer are reported fully later (Section 3H). However in order to preserve the continuity of this hair colour method a brief summary of the results will be presented here.

The first difficulty encountered was the low percentage reflectance found in the hair samples. The maximum reflectance was found at 685 mμ . In the darkest sample this was only 3% reflectance and in the fairest hair sample the maximum reflectance was 36.0%. The minimum reflectances of the samples were at 425 mμ , and the reflectances of the darkest and lightest samples at this point were only 2% and 15%. It was felt that owing to the relative crudity of the measurement there would be inaccuracies in measuring such small reflectances.

When the R values were calculated it was found that according to the class divisions suggested by Reed (1952) the sample contained 4 subjects with copper red hair, 11 with light red hair and 20 with red-brown out of a total of 51. Though the sample had been selected for the extremes of hair colour rather than as a representative cross section of the population these figures could not be accepted as various samples classified as copper red or light red were in fact visually red-brown, and some visually blond samples were classified as light red. The Gardner-MacAdam index gave more satisfactory proportions, classifying the samples as 3 true reds, 13 red-brown and 35 brown. However one of the samples classified as a true red was in fact visually on the borderline between red-brown and brown, and several of the 'red-brown' samples had no visually noticeable red.

2J.10 Attempts to Obtain Access to Another Spectrophotometer

It was decided to attempt to find a more sophisticated spectrophotometer. A visit was paid to Dr.Sunderland of Durham University who gave very useful advice on the matter. The National Physical Laboratory, who had measured the reflectances of Dr.Sunderland's samples in 1955, were contacted. It was found that they no longer used the instrument that had been used in Dr.Sunderland's work, and that the new version of the spectrophotometer required a skilled user. In order to have the samples read upon this machine a charge of two pounds per sample would have been made. It was not possible to afford this sum.

A number of possible sources were contacted, including the University of Birmingham, the West Midland Forensic Science

Laboratory and the Toilet Preparations Federation. This last organization suggested that the Unilever company might be able to advise. A visit was made to the London laboratories of the Unilever company where hair and toilet preparations, are developed. The staff of this centre were most helpful, and would have co-operated in measuring the reflectances of hair samples, but the problem was the size of the hair samples. All the apparatus in the Unilever laboratories required large samples of hair - far more than could be obtained in a voluntary survey. The only apparatus that would have been useable with the size of hair samples available was used for skin colour measurements by Unilever. In brief trials in the London visit it was found that hair samples only registered very low reflectance percentages. It was also suggested that it might be possible to use a new Lovibond tintometer with flexible optical light guides. This would have enabled the hair colour to be measured without taking a sample from the head as the light guide could be held on the subject's head while the colour comparison was done. However this was not a reflectance method but merely a complex comparative method, and it would not have been possible to purchase one of these new comparators for reasons of finance. It would have been necessary to send the samples to London where an experienced technician would have made the comparison. Since it was hoped to obtain true reflectance readings for the hair samples it was decided to decline this most generous offer from Unilever.

In a further attempt to find a suitable instrument the

Interlab Scheme was used. This is a government organization designed to facilitate the communal use of specialized pieces of equipment. A directory of organizations with specialised apparatus is held by the organisers and persons wishing to make use of some obscure equipment are able to contact the appropriate source. In this case it was found that two Midland colleges were concerned with colour measurements, the Lanchester College of Technology in Coventry and the North Staffordshire College of Technology in Stoke-on-Trent. Enquiries were sent to both these colleges; the Lanchester College gave no reply, but a favourable response was obtained from Stoke-on-Trent.

A visit was paid to Stoke-on-Trent and the problem was discussed with Mr. D.S. Dodd of the Physics Department. Mr. Dodd was most helpful and provided a set of the duplicated notes on colour measurement that he gave to his students. Though most of the apparatus at the College required large size samples, the department being concerned chiefly with colour in ceramics, there was one machine, the Hilger-Watts J 40 Colourmaster that only required a sample of 1 cm in diameter. Mr.Dodds suggested that this machine should be used. In addition to the small sample size requirements the J 40 had the further advantages of an internal standard white surface for scale adjustment and an annular photocell, which meant that the orientation of the hair sample was not important. A set of 10 filters was available giving the wavelengths of 390, 420, 470, 500, 520, 550, 580, 610 and 660 $m\mu$. In practice only the nine filters from 420 m were used as it was found that the reflectance at 390 mμ was very low, and the previous workers had not used wavelengths below 400 mμ . It was suggested by Mr. Dodd that the accuracy of the measurement could be improved by adjusting the reflectance scale such that 100% reflectance was obtained from a grey tile. This was done in all the readings of the hair samples and the real reflectances were calculated later. In fact it was not possible to obtain 100% reflectance for the grey tile with all the filters and various correction factors had to be used in the calculations. The tile used was a standard Pilkington Mountain Grey 55.15, one of a range of standard colours used at the college.

2J.11 Use of Tristimulus Values

In addition to measuring the reflectances of specified wavelengths the J 40 would also be used to obtain tristimulus values for colours samples. The Unilever workers had suggested that it might be useful to measure the tristimulus values of the hair as an indication of its colour, and Mr. Dodds also advised that this would be a logical development.

In explanation of the relationship of tristimulus values to colour it is necessary to consider the colour triangle effect. If three standard primary light sources (red, green, blue) are mixed in various proportions the colours formed may be representated in a triangular diagram. The three primary sources are known as tristimuli. In the triangle the colour corner positions represent

100% of the primary stimulus while the side opposite to the corner represents 0% of that colour. The central point of the triangle where equal quantities of each of the three colours are mixed represents white. All the possible colours that can be formed by the three colour stimuli by addition are enclosed within the triangle. However it is found that for any set of red, green and blue there are some colours that cannot be matched by additive combinations of the three colours. These lie outside the colour triangle and can only be matched by using a negative value of one or more of the standard colours.

In order to avoid using a measurement system with negative colour values it is necessary to use tristimuli which will provide a colour triangle that encloses the whole of the spectral locus. This meant that 'imaginary' tristimuli X, Y and Z had to be used. X, Y and Z are not physically realisable colours. By mathematical transformation the final effect is that the whole spectral locus from 380 to 700 mμ is enclosed in a right angled triangle defined in terms of X, Y and Z. Any colour may be specified by stating its tristimulus values. It is usual to derive chromaticity co-ordinates from the tristimulus values, rather than using the tristimulus values directly. The chromaticity co-ordinates are in fact simple ratios of each tristimulus value to the total of the three tristimulus value.

Thus : chromaticity co-ordinate $x = \dfrac{TX}{TX + TY + TZ}$

$$y = \frac{TY}{TX + TY + TZ}$$

$$z = \frac{TZ}{TX + TY + TZ}$$

where TX, TY and TZ are the tristimuli values for the three primary stimuli X, Y and Z.

From this it will be seen that a colour may be defined by two of its chromaticity co-ordinates since these are ratios not real numbers and $x + y + z$ is always equal to one. The original X, Y and Z tristimuli were devised such that Y represented the total darkness of the sample, so it is possible to plot colour in terms of three dimensions by the use of x, y and Y. In order to visualise the colour a line may be drawn from the point on the triangle representing the colour of the illuminant to x, y point and then continued to cut the spectral locus. The point where this line cuts is taken to represent the dominant wavelength of the colour being measured.

It was decided to try out the J.40 apparatus in the pilot survey and to measure both the tristimulus values and reflectance values at nine wavelengths. In fact the X tristimulus is measured by two separate filters in the J.40 colourimeter whereas the Y and Z only require one. This meant a total of 13 measurements for each sample.

2J.12 Hair Colour Determination in Pilot Survey

The samples were taken from the pilot survey subjects and placed in small envelopes. It was possible to obtain quite large samples as the majority of the student subjects had long hair. The samples were washed in dilute Teepol, rinsed, dried and mounted on small pieces of card. It was found that if cards 1" by 2½" were used, with the hair sample mounted in the centre, the whole card could be placed inside the top cap of the J 40 and the specimen was thus automatically placed on top of the light aperture. The hair was attached to the card by transparent adhesive tape at both ends of the lock. Care was taken that no tape was in a position to affect the reflectance measurements. Black paper was placed under the sample to minimise the effects of possible spaces in the sample not covered by hair.

A total of 50 samples were collected and taken to Stoke-on-Trent, where the 13 reflectance values were measured. Owing to pressure of time it was not possible to repeat the wavelength measurements but the four tristimulus readings for each sample were taken twice.

2J.13 Standard Hair Colour Range

A standard hair colour range was prepared from the original trial samples and further samples from suitable volunteers. This was made up of nine hair samples divided into three sets according to their degree of red colouration. Each set contained three grades of darkness. On the darkness scale hair was recorded a lighter than or equal to the first sample, between sample 1 - 2, between 2 and 3 or darker than sample 3, the darkness of the samples increasing from 1 to 3. The redness levels were described as no red, slight red and definite red. Samples were classified as 'no red' if they were less red than the slightly red sample set, 'slightly red' if they were less red than the definitely red samples and 'definitely red' if they equalled or exceeded the redness of the definitely red set.

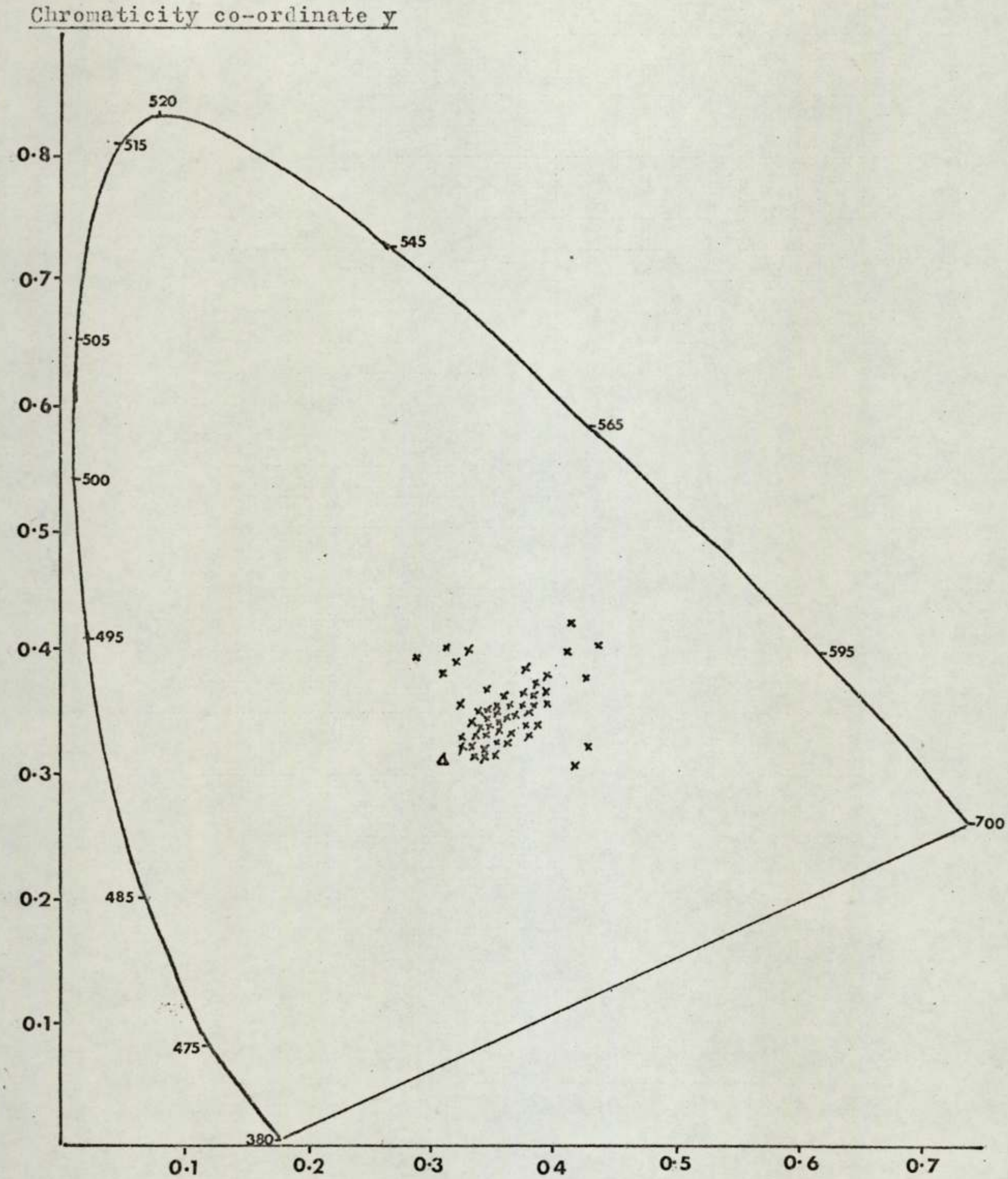
2J.14 Treatment of Pilot Survey Data

The data from the standard colour range comparison was treated as an ordinary discontinuous variable. The reflectance values were used to calculate the tristimulus values and chromaticity co-ordinates. Approximations of the R index and the Gardner-MacAdam Index were also calculated.

When the chromaticity co-ordinates had been calculated they were plotted on a colour triangle with the spectral locus. The co-ordinates of the spectral locus were obtained from Wysecki and Stiles (1967) (see fig.3). When the dominant wavelength of the samples were estimated it was found that several obtained values in the green part of the spectrum. No explanation for this could be found, as there was good agreement between the duplicate readings in each case. None of the samples was visibly green.

It was possible to calculate 4 approximations of the R index, in each case using reflectance on 660 mμ as the divisor.

Fig. 3. Spectral locus plotted to show distribution of chromaticity co-ordinates of pilot survey hair samples



Δ = Source C.

Wavelengths indicated at points on spectral locus.

Note: in the most densely occupied area of the graph a small number of points have been omitted for the sake of clarity.

For the 530 mμ reflectance, 520 mμ and 550 mμ were substituted and for 400 mμ the values at 420 mμ and 440 mμ were used. Of the 50 samples obtained from the pilot survey only two were visually red. However in each of the four R value calculations it was found that the majority of the population appeared to be red haired. Even if the division points had been modified from those suggested by Reed (1952) there would still have been a considerable overlap with non-red hair being classified with the red samples. The Gardner-MacAdam index was calculated as reflectance 550 mμ/reflectance at 600. None of the samples was scored as a true red, but the two red samples were classified as red-brown along with a very neutral non-red colour sample. In view of the rather unsatisfactory nature of these results it was decided to enquire further about the possibility of using some other spectrophotometer.

2K.15 Apparatus at University of Aston Optics Department

At this stage it was discovered that there had been an earlier gap in communication. When the Physics Department at Aston had stated that their only colour-measuring apparatus was the E.E.L. Spectrophotometer, they had not been speaking for the sub-department of Ophthalmic Optics. It was found that this sub-department possessed a variety of colour measuring apparatus, including the Hilger J 50 that had been used in Stoke-on-Trent.

However in a full discussion of the problem with Mr. H.C. Yorke of the Optics Department it was concluded that use of complex measuring apparatus was in fact inferior to visual colour matching. In this case the hair samples were in general of dark shade and of low colour intensity. It was decided that classification by means of the Munsell system of colour notation would give as meaningful results as reflectance spectrophotometry.

2J.16 Munsell System of Colour Notation

In this system colours are identified in terms of three attributes: hue, value and chroma. The hue of a specimen is related to the major wavelengths reflected from the surface when illuminated by white light. In the Munsell system there are 10 major hues, Red, Yellow Red, Yellow, Green-Yellow, Green, Blue-Green, Blue, Purple Blue, Purple and Red-Purple. There are 4 main divisions with each hue, for example the division from almost green-yellow to almost blue-green. The hue divisions are specified by the initial letter or letters of the hue, plus one of the numbers 2.5, 5.0, 7.5, 10.0. It is possible to obtain standard hues between these divisions but for general work the total colour range is thus divided into 40 parts.

The value of the sample indicates its lightness or darkness. This is measured in relation to a neutral grey scale which extends from absolute black to absolute white. The symbol 0/ indicates black, 5/ mid-grey and 10/ white.

The chroma of the sample indicates the colour intensity of the sample within a given hue division. In other words this is the degree of departure of a given hue from a neutral grey of the same value (or darkness). The chroma can range from /0 for neutral grey as far as /12 or /14 for very vivid colours.

The Munsell System therefore specifies a colour in three dimensions: hue, darkness and colour intensity. A colour is specified by its hue, value and chroma as a shorthand notation. A rose-pink might be specified as 5R 5/4. This gives rise to the concept of a colour space in which the vertical axis caries from black to white, while the 10 major hues are equally spaced around this axis to form a colour cylinder. The chroma or colour intensity is represented by the colour's distance from the central axis along a radius of the hue circle. In fact a regular cylinder is not formed owing to the difference in potential colour intensities.

In the Munsell colour charts each page represents a vertical slice down a radius of the colour cylinder. The standard colours are represented by small 'colour chips' of paper stuck onto the page in appropriate positions. The left hand edge of the page bears the /1 chroma range (nearly neutral) and the chroma or colour intensity increased from left to right. The value or darkness increases from the top to the bottom of the page. Thus a page of a typical Munsell colour book might have colour chips for values from 2/ to 8/ and chroma levels from /1 to /8. Similar pages would be available for every hue division.

2J.17 Use of Munsell Colour Notation in Present Sample

It was decided to try out the use of the Munsell system using the pilot survey samples and a few of the more extreme colour samples from the main survey. The samples were classified using a set of Munsell colour charts intended for soil classification, which was borrowed from the Optics Department. In fact Munsell do produce sets of charts for classifying hair, eye and skin colours, but in this case only the yellow/brown/red range was required and these charts were available in the soil range.

Each chart of the soil series contained the colour chips arranged on a neutral grey background with a 1 cm diameter hole cutting the edge of each chip. A further neutral grey sheet was positioned under the sheet bearing the colour chips. In order to match the sample the small card with the hair attached was placed under the perforated sheet with the colour chips and moved until it was in contact with the most similar of the colour chips. While this operation was in progress the majority of the colour chips were masked with a neutral grey card with a hole in it, so that only 4 colour chips could be seen at any one time. This method was used to avoid confusion owing to the large number of shades of brown that were present.

It was found that all the yellow to brown hair colours could be classified in terms of Hue 10 Y R. Only the visually red colours required another Hue Chart. In addition it was found that all the red samples could be classified by the use of three further colour chips, Hue 7.5YR 3/3, 4/4 and 5/6. The 10 YR chart and the three supplementary chips were purchased for use in the survey.

The samples from the pilot survey and the specially selected red and fair samples were classified according to the Munsell system, and the classification was then repeated on two successive days. The same standard colour matching lamp that had been used during the eye colour, colour vision and hair sample range comparisons was used. It was found that the hair colour classificationson the Munsell system were reproducable and that the only values that varied from day to day were those that were in fact borderline between two colour chips.

It was decided to use the system in the main survey. In practice this meant that hair colour could be analysed in terms of hue, chroma and value in addition to the assessment of hair colour by visual comparison with a range of standard hair colours. Though the Munsell colour classification system is dependant on the accuracy of the eye of the observer it is probable that this system is of equivalent accuracy to the Lovibond system, which also requires human assessment.

The decision to use the Munsell System rather than a reflectance system was taken with regret as it was hoped to obtain a truly objective measure of hair colour. However owing to the lack of success with use of spectrophotometers it was felt that more information would be obtained from the use of a simple comparative system rather than concealing the data in more complex mathematics.

All the samples from the main survey were prepared by washing,etc., as in the pilot survey. In view of the number of samples this was a somewhat complex operation. As each hair sample was cut it was placed in a small envelope that had previously been marked with the subject's reference number. At the time of cleaning the hair sample it was necessary to wash, rinse, dry and mount each hair sample without losing its reference number. This was successfully achieved in all but a very few cases.

Though it was hoped to obtain a lock of hair wide enough to cover a postage stamp and 1" long it was found that many of the schoolchildren were unwilling to give so large a sample. In some cases they were unable to provide this length of hair owing to the then current fashion for a very short "skinhead" haircut. Many samples would have had to be discarded owing to their small size if the reflectance values were measured, but it was possible to classify even these small samples by the Munsell method.

2K - Hair Form

2K.1 Heredity of Hair Type

It has been suggested (Hill and Hill, (1955) that the degree of curl of a hair depends on its shape in cross section. Hairs which are round in cross section tend to be straighter than those which are oval. This difference may be due to a single gene pair showing incomplete dominance in the heterozygote. Rostrand & Tetry (1965) propose that the factor producing curly hair dominates those producing wavy or straight hair, and the factor for wavy hair is dominant over that producing straight hair.

2K.2 Studies of Human Hair Shape in Cross Section

Luell & Archer (1964) noted that the diameter of human head hair increased with age. Seibert & Steggarda (1943) noted that the cross section area of the subject' hair increased rapidly between the ages of ten and thirty but then decreased until the childhood size was reached again at sixty. It was also noted (Steggarda & Seibert 1941) that hairs from males tended to be rounder than hairs from females, and that hair from negroes was more elliptical in cross section than that of other races. A sex difference was also noted by Walsh & Chapman (1966). Duggins & Trotter (1951) noted that there was greater variation in shape of the cross sections of hairs of any individual, though it would seem difficult to establish this in view of the problem of alignment of the hairs when the sections are cut. Spearman & Barnicot (1960) found that the curved hairs of negroes had a greater concentration of melanin on the inside of the curve in comparison with straight hair where the pigment was evenly distributed.

2K.3 Classification of Hair Types

Montague (1960) has suggested that it might be possible to measure the curve that the hair follows. This method would present problems in comparing subjects with hair of different lengths as gravity also affects long hair. In a family study Kloepfer (1946) drew a sketch of the hair type of each subject and then classified the drawing by a standard scale.

In the present survey it was decided to use a four point scale for classifying hair type. A standard range of hair forms representing the four classes was made up from human hair samples obtained from a wig manufacturer. This standard range was held close to the subject's hair and their hair type was noted as straight, slight wave, deep wave or curly. Subjects were asked whether their hair was in its natural state. None were found to have had any permanent wave treatment at the time of the interview, though some girls stated that they had set their hair on rollers. None of these cases would have been classified as deeply-waved even if the possibly artificial nature of the hair type had not been known. These girls were asked to give an honest assessment of their natural hair type, and the report was entered on their record sheet. It was not felt that this would introduce much bias into the survey. Any bias would probably be in the direction of an excess of straight haired females, as it was found that even females with observable slightly wavy hair would report that their hair was straight during the interview.

2L - Hair Line (Widow's Peak)

2L.1 Heredity of Hairline Type

In a certain proportion of the population there is a slight downward extension in the centre of the hair line. This gives the effect of a "peak" of hair, thus giving rise to the common name of this characteristic. The extent of the peak varies from very slight irregularities in the hair line to true peaks of measureable length.

Scheinfeld (1965) states that the presence of a widow's peak is due to a dominant gene, and Winchester (1964) includes this trait in a group of inherited characteristics. However in the twin survey included in the present project the trait was only found to have a heritability of 0.39. Though it appears that other factors than heredity may influence hair line type it was decided to include the trait in the survey because of its easy recognition.

2L.2 Method of Classifying Hair Line Type

There is no accepted method of classifying hair line types. It was therefore decided to use a standard scale of drawings of hair line types and classify the subjects by comparison with this scale. In a previous study (Wheatcroft 1967) hair lines had been classified as having a definite widow's peak present or absent. This meant that intermediate types were included in the absent class, but in the present survey it was decided to keep the intermediate hair line types as a separate category. (see fig.4)

2M - Ear Lobe Type

2M.1 Genetic Background of Ear Lobe Type

Observation of any human population will show that there is considerable variation in the degree of attachment of the lobe part of the outer ear. In some cases there is a flap of tissue

Fig. 4. Hair line scale

Level

Irregular

Widow's peak

which hangs freely from the tragus of the ear, while in others this lobe is either attached as is the main part of the ear, or entirely absent. In a family study, Powell & Whitney (1937) concluded that the factor producing attached lobes was a single Mendelian recessive. However ear lobes do not conform to two distinct types, there is rather a continuous range of types between two extremes. Dutta & Ganguly (1965) have suggested that polygenic factors may determine ear lobe type. In another family study in 1937, Wiener found that although there was a definite correlation between the ear lobe types of parents and children the data did not agree with simple Mendelian inheritance. More recently Lai and Walsh (1966) agreed that family data collected from many countries was not consistent with single gene inheritance.

2M.2 Classification of Ear Lobe Types

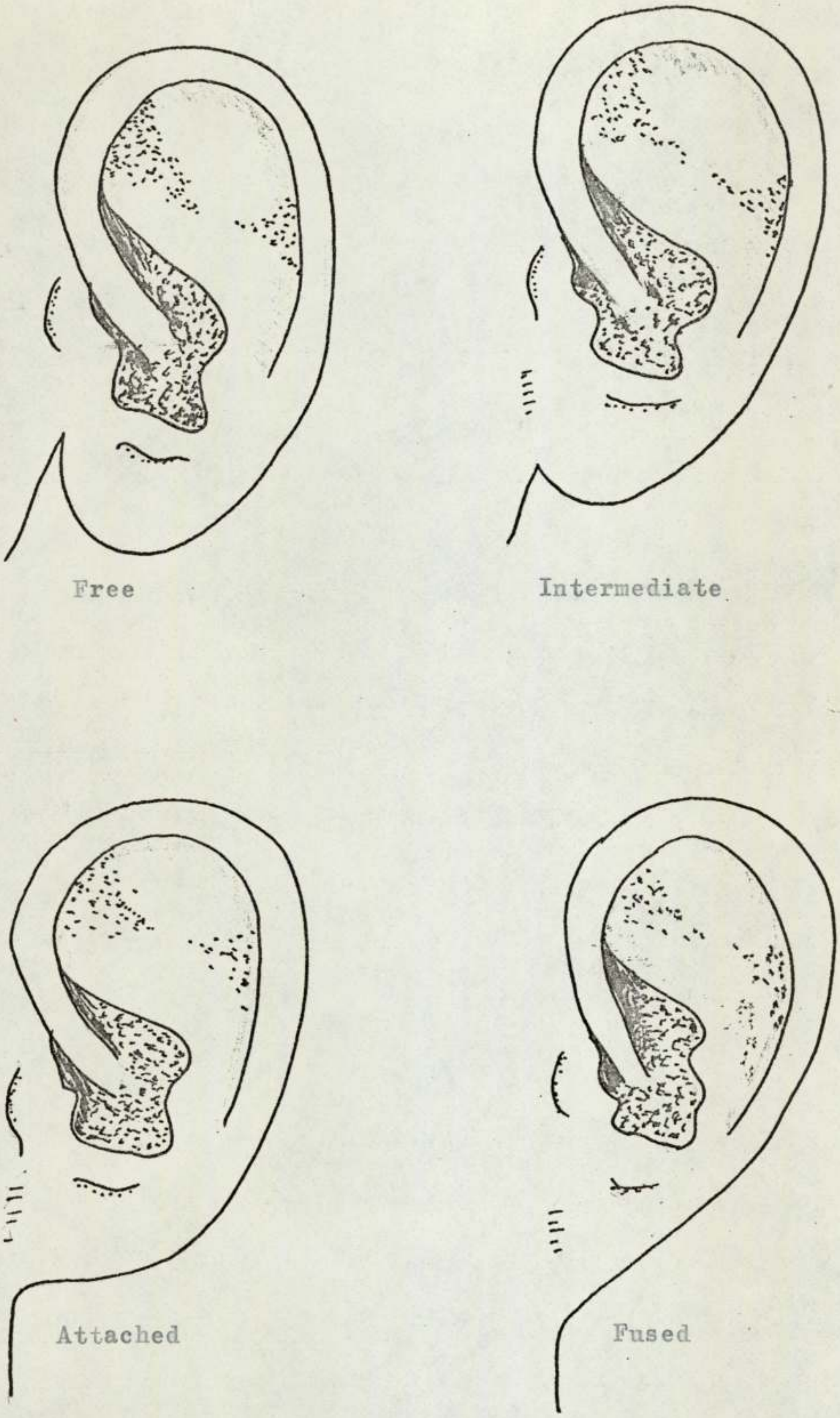
It seems likely that the best method of characterising ear lobe type would be to take comprehensive measurements of the ear. Vollmer (1937) suggested that one could measure ear lobe attachment and this measurement has been included in anthropological surveys (Hertzberg et al 1963). There are considerable difficulties in measuring the length of the ear lobe as it is both flexible and compressible. This lack of rigidity makes it hard to obtain consistent results. A small scale trial was carried out to test the reproducability of results of ear measurements using a small anthropometer. These results were not encouraging, and so it was decided not to use measurements in this survey.

The alternative method is to classify ear lobe types either by a simple nominal scale such as free, intermediate, attached, or by a series of standard pictures of ear types. The nominal classification method has been used in the majority of the surveys so far. In many surveys ear lobes are classified simply as attached or free. This method was used by Glass in his study of Dunkers (1956, Glass et al 1952), Riddell (1941) in Scottish children, Dutta (1963) in a study of different races, Bhasin (1969) in a study of Nepalese and Lai and Walsh (1966) in a comparison of racial group. Other workers have preferred to divide ear lobe type into three groups: free, intermediate and attached. Those using this scheme of classification include Dutta and Ganguly (1965), Dronamraju (1966), Tiwari and Bhasin (1969), Das (1967) and Brues (1950). Wiener (1937) suggested that there should be a four part scale of ear lobe type, there being two classes of intermediate. Hooton and Dupertuis (1955) recognised two types of attached ear lobe; the simple attached lobe and the lobe that was almost absent. This latter type is often referred to in the literature as 'soldered' or 'fused'.

Vollmer (1937) gives drawings of different ear lobe types, but only one investigator using drawings of ears has been noted. Kloepfer (1947) made drawings of the subjects' ear lobe type at the time of the interview and then classified the drawings later. It was decided to use a standard range of pictures of ear lobe types in the present survey (see fig.5). The ear lobes were drawn to represent the four main types of ear lobe that were noted in the

Fig. 5.

Ear type scale



population; free, intermediate, attached and fused. The pilot survey showed that it was possible to classify subjects by comparison with this standard range and it was therefore used in the main survey.

2N - Chin Type

2N.1 Previous Studies in Chin Type

A certain proportion of the population possess a central vertical indentation in the lower margin of their chin. This is commonly known as a "cleft" chin. This characteristic is more commonly referred to in popular and general genetic texts than in surveys of an anthropological nature. However these texts that mention this characteristic are unanimous in their view that it is inherited, and that the inheritance follows Mendelian segregation Hill and Hill (1955), Rostrand and Tetry (1965) and Scheinfeld (1965) agree that the factor determining a cleft chin is inherited as a dominant over that for a non-cleft chin.

In a collection of photographs of seven generations of a family, Lebow and Sawin (1941) noted that the factor producing a cleft chin appeared to be recessive. However Krogman (1967) in a review article on the genetic factors influencing the face notes that cleft chin is said to be inherited as a simple dominant. In a twin survey he quotes a vertical chin groove was found to be an autosomal dominant with penetrance of 100%. It is difficult to reconcile these two views, and it may be that the inheritance of chin type is complex.

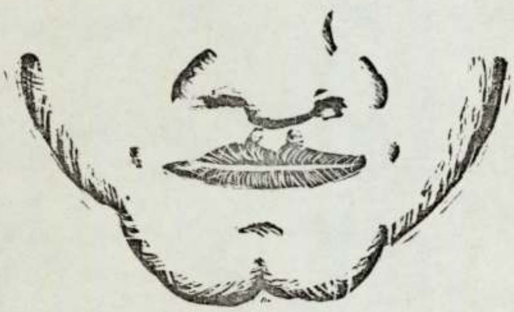
2N.2 Classification of Chin Types

There are in practice a whole range of chin types. The simple vertical cleft occurs in wide range of depths ranging from a slight indentation to a definite furrow. There are also some cases where there is an isolated indentation mid-way between the lower lip and the lower margin of the chin. Such cases are commonly said to have a dimple in their chin. Though it may well be that these different types of chin indentation represent the variable expression of a single factor, it was thought worthwhile to collect the frequencies of the various chin types separately.

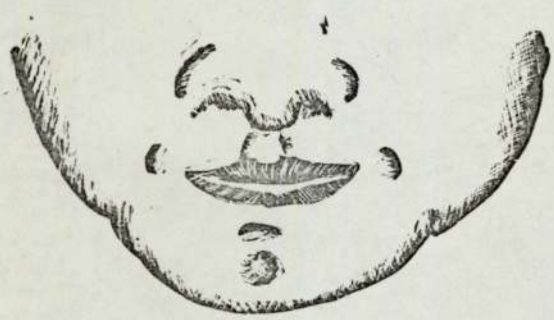
It might be possible to define the type and extent of a chin indentation by means of extensive and detailed anthropometry. In this survey the time taken to interview each subject was very limited and so this method could not be attempted. It was decided to classify the chin types by comparison with a simple pictorial scale. Originally the intention was to provide a photographic scale, but photography of the chins of suitable volunteers showed that it was not possible to obtain a clear representation of the degree of indentation. A standard scale was therefore drawn, the types of chin represented being whole, slight cleft, definite cleft and dimple. (see fig.6) The pilot survey showed that this scale was usable and it was therefore employed in the main survey. All subjects' chins were examined with great care, using supplementary

Fig. 6. Chin type scale

Slight cleft



Definite cleft



Dimple

lighting to ensure that even slight indentations were noticed.

20 - Freckling

20.1 Heredity of Freckling

A proportion of the population have small patches of skin that produce more pigment than the surrounding area. These patches, commonly called freckles, are stimulated to produce extra pigment by sunlight. Freckles are therefore most apparent on the areas of the body that receive more exposure, usually the face and arms (Auerbach, 1962). Nicholls (1968) suggested that this effect is due to a type of mosaicism. He noted that red hair and freckles were associated, and that there was a variation in colour between different hairs from a red haired freckled person. This might be interpreted as another manifestation of mosaicism.

In a family study Nicholls (1969) found that his data supported the hypothesis that this trait is determined by a gene which produces dark hair with freckles in the heterozygote and red hair with freckles in the homozygote. He also noted that the frequency of pigmented birthmarks in the different groups supported the theory that these marks arise by somatic mutation of the freckling gene.

20.2 Method of Classification of Skin Types

Hooton and Dupertuis (1955) divided their survey population into two groups, those with freckles and those without. This simple classification does not take into account the wide range or density of freckling that occurs in most populations. Brues (1950) noted three skin types; those without freckles, those with few freckles and those with many.

It is difficult to devise an accurate method of measuring density of freckling in an individual. In theory it would be possible to mark off a standard area of the face and count the number of freckles within this area. Such a method would certainly try the patience of the subject, but it would in any case be inaccurate as the areas in which freckles are present may differ in persons having the same density of freckles. In most persons with freckles the area containing the majority of the freckles is centred on the nose. The nose and upper cheeks are freckled but the rest of the face is not. In others the whole of the face is evenly covered with freckles and there is less concentration in the centre of the face.

In the present survey it was decided to classify the subjects as having no freckles, light freckling or heavy freckling. Those with light freckling had the freckles concentrated in the centre of the face while those with heavy freckling had the freckles distributed more evenly over the whole face.

2P - Mid-Digital Hair

2P.1 Background and Heredity of Mid-Digital Hair

A majority of the British population have hairs on the second phalanges of their fingers (Brothwell & Molleson 1965). The number of fingers possessing this characteristic is variable, but the presence of hair appears to centre upon the 4th digit (Garn 1950, Saldanha & Guinsberg 1961). All the usual patterns of presence of hair include the 4th digit. Hairs may be present on the fourth digit alone, the third and fourth, the third, fourth and fifth digits or on all digits excluding the thumb (Danforth 1921). Occasional cases are found that do not fit any of these patterns, but it is probable that these differences are due to loss of hair from one or more digits. Garn (1950) has noted that all the hairs potentially present may not be seen owing to their cycle of growth and replacement. In females it is possible that some hairs are rudimentary (Danforth 1921) or lost owing to constant manual work (Bernstein and Burks 1941).

Rostrand and Tetry (1965) suggest that the presence of mid-digital hair is a dominant Mendelian characteristic. The variability of this characteristic requires a more complex explanation than this. Glass (1952) suggested that there is a multiple allelic series responsible for the characteristic. He postulates a series of five alleles, Md_o to Md_4, controlling the number of fingers with mid-digital hair. Dominance would be in ascending order from Md_o (no MDH) to Md_4 (all four fingers with hair). A similar theory was put forward by Bernstein and Burks (1942) and Bernstein (1942, 1949). Sib data was found to fit either the hypothesis of monogenic recessivity or more random combination. (Saldanha and Guinsberg 1961). Beckman and Book (1959) noted that presence of MDH was inherited as a dominant factor. Hair is also present on the middle phalanges of the toes, but Rakshit (1965) noted that the frequencies of the various patterns differed from the finger pattern distribution. Setty (1966ab) noted that the presence of MDH on the hand was associated with MDH on the toes. He also suggested that there was a possibility that MDH patterns were associated with the hair patterns of the hand, and the arm (1964).

2P.2 Method of Classification of MDH Types

It is necessary to examine the fingers of both hands and note the presence or absence of hairs on each digit. Basu (1967), Srivastara (1966) and Saldanha and Guinsberg (1961) recommend that a pocket lens should be used for close examination. Basu also suggests that the fingers should previously be cleaned using a mixture of absolute alcohol and carbon tetrachloride, and Srivastara suggests using spirit alone as a cleansing agent.

In the present survey the fingers of the subject were examined using a x 10 lens, and supplementary lighting. It was not found necessary to clean the fingers of the majority of the subjects, though a small phial of absolute alcohol was included in the survey apparatus for this purpose. Occasionally subjects came to the interview directly after games or art periods, in which case it was necessary to remove excess mud or paint. When one finger was obscured by a bandage that could not be removed this was noted as a query, and classification was carried out using the equivalent finger of the other hand.

The classification of the MDH type in the present survey took account of both the subjects' hands. When hair was present on a finger of one hand but not on the corresponding finger of the other hand this was scored as a positive result. It seems probable that some subjects would have lost hairs on one hand while retaining the basic pattern on the other hand. Saldanha and Guinsberg (1961) noted that small differences between hands could be environmental or hormonal. Ganguly and Pal (1963) noted that the differences between the hands of an individual were negligibly small.

In the interests of clarity it was decided to refer to the different mid-digital hair types as MDH 0, MDH 1, MDH 2, MDH 3, MDH 4, according to the number of fingers with hair. This nomenclature has been used throughout the report. A full key to these abbreviations is given below:

MDH 0 = no mid-digital hair

MDH 1 = MDH on digit 4 only

MDH 2 = MDH on digits 3 & 4

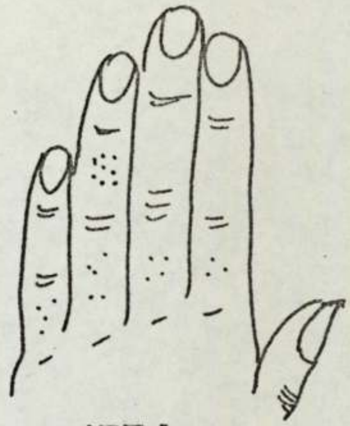
MDH 3 = MDH on digits 3, 4 and 5

MDH 4 = MDH on digits 2, 3, 4 and 5.

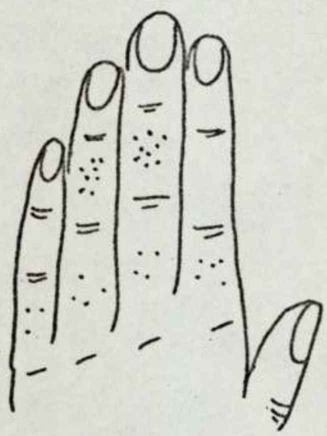
MDH X = MDH pattern other than one of the above (see fig.7) (lumped with MDH 4 in tabulation).

Fig. 7. Mid-digital hair scale

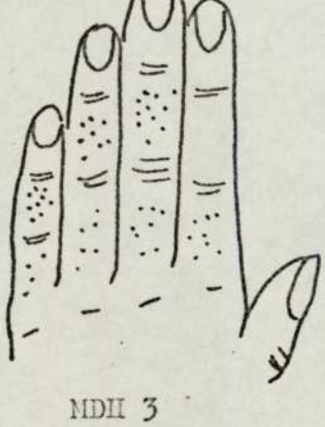
MDH 0



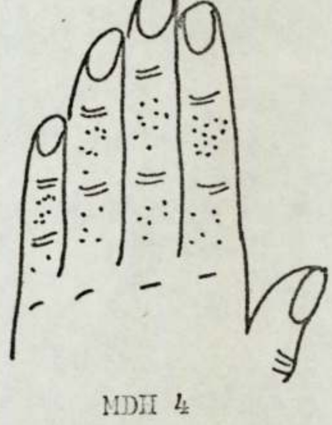
MDH 1



MDH 2



MDH 3



MDH 4

2Q - Finger Length

2Q.1 Variations in Relative Finger Length

When the hand is placed palm downwards on a flat surface the relative lengths of the index finger (2nd digit) and ring finger (4th digit) may be classified. Three patterns are found: 2nd digit longer than 4th, both equal or 4th longer. (George 1930), Phelps 1952, Blincoe 1962) (see fig.8). Another hand variation sometimes studies is the relative lengths of the fourth and fifth digits, the fifth digit being classified according to its relation to the distal joint of the fourth finger (Glass et al 1952, Glass 1956, Blincoe 1962). It is not known whether there is any association between these two traits but it is probable that they are different manifestations of the same basic difference in hand type.

2Q.2 Methods of Classifying Hand Type

It was decided to include only the index/ring-finger comparison in the present survey (Wheatcroft 1967) had shown that the range of variation in the 4th/5th digit types was on average small. This meant that classification was sometime uncertain.

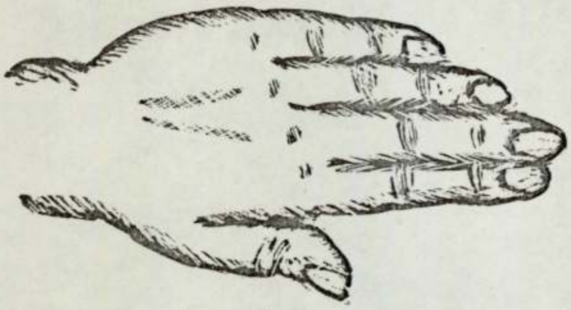
George (1930) devised a special 'finger board' for measuring the relative lengths of the 2nd and 4th digits. This consisted of a flat board with a fixed block for the 3rd digit to rest against and scaled markers which slip down to meet the 2nd and 4th digits. Only right hands were measured in this survey.

In 1952 Phelps classified hand types by tracing the subject's left hand and then measuring the tracing with a pivot ruler. This method would seem to introduce various problems of accuracy, however a similar method was used by Rosler (1957). Other surveys (Kloepfer 1946, Blincoe 1962) merely examined the subject's hand when it was resting on a flat surface.

In the present survey it was decided that tracing the outline of the hand would be too time-consuming and also that it would be difficult to obtain an accurate tracing. The finger board designed by George (1930) was considered, but this device appeared to make classification more complex, without providing a measurement of the actual finger lengths. It was decided to assess hand type by inspection of the subject's left hand laid flat on the working surface. In any cases of doubt a clear plastic protractor was available. This was laid on the back of the subject's hand with the base line towards the finger-tips and the perpendicular along the length of the 3rd digit. By moving the protractor along the finger the positions of the 2nd and 4th fingers in relation to the basic line could be seen, and from their relative lengths could be noted. The left hand was used in order to minimise the environmental effects of muscle building noted by Rosler (1957), though it was accepted that this might lead to some inaccuracy in left-handed subjects.

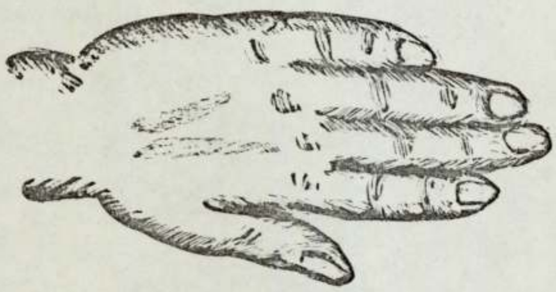
Ideally the different hand types would be studied by examination of x-ray photographs of the subjects' hands. This method

Fig. 8. Finger length scale



long index

equal



long ring

was used in a study of toe types Venning (1956), but Kaplan (1963, 1964) classified various toe types by examination only. It is possible that the visible differences in hand type are not in fact skeletal in origin but rather due to differences in musculature.

2R - PTC Tasting

2R.1 Discovery of PTC Tasting

The taste properties of phenylthiocarbamide were first noted by Fox (1932). In fact it was a colleague of Fox's who noticed that the dust from the PTC Fox was using had a bitter taste. Fox himself was unable to detect any taste in the crystals, though he later made the experiment of dissolving PTC crystals in saliva from a person able to taste PTC (Fox 1932).

2R.2 Chemistry of Compounds Showing the PTC Taste Reaction

Fox found that all compounds containing the grouping $NH - \underset{\underset{S}{\|}}{C} - NH$ showed the same taste dichtomy as PTC. Harris and Kalmus (1949) found that seven other thio-compounds were similar to PTC in their taste reactions. Eighteen more compounds were tested by Barnicot and co-workers in 1951. They concluded that the grouping $N = C = S$ is necessary for the PTC taste reaction, but $N = C = O$ does not give the same effect. Goedde and Oligmacher (1965, 1966) found that anetholtrithion, which does not contain the $N = C = S$

grouping, have a taste reaction. This was confirmed as similar to the PTC reaction by Dawson and co-workers in 1967.

2R.3 Genetics of PTC Tasting

Blakeslee (1932 ab) suggested that the ability to taste PTC was inherited as a single Mendelian dominant, with non-tasters forming the double recessive class. However Levine and Anderson (1932) noted that some parents with low taste sensitivity had taster children. Later work has shown that the situation is far from simple. Das (1956a) found that the data from sib pairs agreed better with the Mendelian inheritance theory than with a theory of random combination of taste acuities. He suggested that there might be incomplete penetrance of the factors determining the ability to taste PTC, and proposed that the penetrance might be 90% (Das 1958). Pons (1960) found that sib pair data was in agreement with the simple recessive character being responsible for the lack of ability to taste PTC. But Harris and Kalmus (1950) were unable to confirm the simple recessive character theory as their sib pair data did not fit this theory, nor could their results be explained as random combinations of taste ability. Merton (1958) found that family data on PTC tasting fitted Mendelian inheritance, but sib pair data did not.

The data of PTC tasting in twins is fully discussed in the twin section (4D.14). However the general conclusion from the twin data is that there is often considerable variation in taste sensitivity between the members of a monozygotic twin pair. If incomplete penetrance for this factor is the case, this may explain the twin differences in PTC tasting.

The variation in range of taste sensitivities in different populations has led some workers to suggest that there may be a third allele responsible for extremely sensitive taste ability (Rychkov and Borodina 1969). Lugg (1962, 1966) has noted the distribution of PTC taste abilities is probably multimodal. He suggests that this could be interpreted as supporting a multi-allelic system of PTC taste factors.

2R.4 Methods of PTC Taste Testing

Ever since it was established that PTC tasting was an inherited characteristic, the trait has been used in anthropological surveys at many levels of complexity. These will be described more fully in the discussion section. Various methods have been devised for testing the PTC taste reaction and in many cases the method used is decided by the circumstances of the survey.

In the earliest surveys PTC crystals were used, either alone or in comparison with a PTC solution (Fox 1932, Blakeslee 1932ab, Cohen and Ogden 1949a, Riddell and Wybar 1944). Attempts to standardize the PTC taste test by using PTC paper have had some success, and this method has been used as recently as 1969. (Parr 1934, Terry and Segall 1947, Hutt 1947, Hoover 1956, Hoyne 1955, Soltan and Bracken 1958, Taylor 1961, Johnson et al 1966 and

Milunicova et al 1969). Hartmann (1939) compared PTC papers, crystals and solutions and found that rather more persons were classified as tasters using crystals or paper than using solutions.

Some surveys have used a single PTC solution to divide groups into tasters and non-tasters. Riddell and Wybar (1944) used 0.005% PTC solution, while Cohen and Ogden (1949) used a saturated solution. Bhattacharya (1964) used a solution of 1300 ppm, Guttman and co-workers used 1 g per litre (1000 ppm), Hauge and Helweg Larsen (1953) used 40 ppm and Mann (1969) used 50 ppm. Blakeslee (1932) used four concentrations of PTC while Sanghvi and Khanolkar (1950) used three concentrations. In a survey of students Wheatcroft (1967) used PTC solution of 80 ppm made up as a jelly for ease of transport.

A more detailed method of determination of the taste threshold uses a serial dilution of a PTC solution. In this method the resulting distribution of PTC taste thresholds is usually bimodal, one mode represents the taster population and one the non-tasters. This method was first used by Hartmann in 1939. She used a starting concentration of 2600 ppm, and dilutions of this and resulting solutions by a half to give a series of 14 dilutions. Falconer (1947) also used serial dilutions of PTC but in this case the initial concentration was 1800 ppm. Eleven dilutions were used in this case. Beach (1953) used a series of dilution from 1600 ppm. The most commonly employed procedure for estimating the taste threshold for PTC is that devised by Harris and Kalmus (1949). They used an initial concentration of 1300ppm. This solution was then diluted by half to give a series of 13 solutions, the weakest containing 0.32 ppm.

In the testing procedure in the Harris and Kalmus method the subject is asked to taste each of the dilutions in turn, starting from the most dilute solution. When the subject is able to detect a definite taste in a solution this solution is used in a sorting test to determine whether the subject is able to sort the PTC solution from water. Eight cups or beakers are offered to the subject, four containing water and four the PTC solution. The cups are marked so that the tester knows the contents, and presented to the subject in a random order. If the subject is able to sort the PTC solutions from the water correctly, the sorting test is repeated using the next weakest dilution, and the testing is continued until a dilution is found that the subject cannot sort out from water. When the subject is not able to carry out the first sorting test correctly the next most concentrated solution is used in a second sorting test, and testing is continued until a concentration is reached that can be distinguished from water. The taste threshold is taken as the lowest concentration that can be distinguished from water is a sorting test. While the testing is being carried out the subject is allowed an unlimited amount of the PTC solution s and water, the beakers being refilled if necessary.

Since the Harris and Kalmus method required a large number of solutions to be tasted it is somewhat time-consuming. Various modifications of this procedure have been used. Sunderland (1966) uses only eight solutions out of the Harris and Kalmus range (1, 3, 4, 5, 6, 7, 9, 11), including those which cover the possible placing of the antimode. This procedure is also used by Cartwright and Sunderland (1967) and Sunderland and Ryman (1968). Allison (1951) and Allison and Nevanlinna (1952) compromise by using alternate solutions of the Harris and Kalmus series. Thus they have a series of seven solutions equivalent to Harris and Kalmus's 1, 3, 5, 7, 9, 11, 13. Giles and co-workers (1968) used Harris and Kalmus solutions 2 to 8, as did Azevedo (1965).

Other workers have used the whole range of solutions but used a less exacting method of administering the solution to be tasted. Azevedo (1965) used plastic squirt bottles, with the PTC solution in a cellophane liner inside. The solution was then squirted directly into the mouths of the subjects. Lugg and White (1955) used a spoon or a dropping pipette to give the subjects 2.5cc of the PTC solution or water. This was then rinsed round the mouth and spat out. In the preliminary testing the sequence of administration was water, PTC, water, and in the sorting tests the sequence was water, PTC, water, PTC. This method was used by Lugg in later papers (1963, 1964a, 1968). Lugg (1968) has also increased the number of dilutions used in the Harris and Kalmus procedure, using up to 24 dilutions in some cases. Kalmus (1958) suggested the use of quinine tasting to distinguish those subjects of overall low taste sensitivity.

2R.5 Testing Procedure in the Present Survey

It was decided to use the full 13 dilution range of the Harris and Kalmus method, as it was felt that shortening the range might result in a loss of valuable data. Although Dr. E. Sunderland had advised the use of glass beakers for taste testing it was found that this was not practicable in this particular field situation, as the survey was being carried out single handed. Since numbers of up to thirty subjects per day were being interviewed it would have been necessary to transport 240 small glass beakers from school to school. However when a visit was made to Professor H. Kalmus he suggested that empty plastic yoghurt pots could be used in taste testing. In lieu of an adequate number of such vessels it was decided to purchase a large number of small disposable plastic cups, which could be used once and then discarded. This eliminated the cleaning problem. Initially 2oz plastic cups were used but later 1oz cups were found to be adequate. The cups were counted out into sets of eight in the pilot survey and five in the main survey, and numbered before the testing commenced. It was found convenient to make up boxes of thirty sets of cups in advance so that these could be used as required. The PTC solutions were stored in rigid polypropylene bottles either 500ml or 250ml. Though some doubt was felt over the possibility of the solutions acquiring a taste from the polypropylene bottles preliminary trials showed that the taste change over periods of a few days were not appreciable. In fact during the periods of active surveying the PTC solutions were used up at such a rate that it was necessary to refill each bottle at least every second day. When refilling the bottles any remaining PTC solution was discarded and freshly made up PTC used to fill the bottle. The stock solution of 1300 pmm was kept in a glass bottle. The stock solution was prepared by dissolving 1.3g of British Drug Houses Laboratory Reagent Grade phenylthiocarbamide in distilled water and then making the resulting solution up to one litre. Distilled water was used rather than tap water as it was found that in certain concentrations of PTC in tap water a loose brown precipitate was formed. This may have been due to the chelating action of the PTC on dissolved metal ions in the water. The remaining PTC solutions were prepared by a serial dilution of the stock 1300 ppm solution by one half. Distilled water was used as the diluting agent in each case. Distilled water was also used as the control in the sorting test. The distilled water for this purpose was carried in the same type of 500ml polypropylene bottles as the PTC solutions. Although it would have been possible to carry a larger reservoir of distilled water it was felt that there might be temperature differences between different volumes of liquid.

In general it was found that 500cc of PTC solutions 7-13 and 250cc of solutions 1-6 was ample for a day's sampling. In some cases there was an unusual distribution of taste thresholds at a particular school and it was necessary to refill one of the PTC bottles in the field. For this purpose a 500ml polypropylene measuring cylinder, a glass 25ml measuring cylinder and a 1000ml polypropylene beaker were included in the survey equipment. When it became necessary to renew a solution a small quantity of a more concentrated solution was taken and diluted to the appropriate level, using distilled water.

2R.6 Testing Procedure

In the pilot survey the full Harris and Kalmus technique was used, with eight cups in the sorting test. A set of eight cups was taken from the box, and between ten and twenty cc of the most dilute PTC solution were put into it. The subject was then invited to taste it, spitting it out if he wished, and then to tell the interviewer whether it was ordinary water or whether it had any definite taste. Ordinary distilled water was available for comparison if the subject desired. The tasting procedure was then continued as described in Section 2R.4. Any remains of the first solution were tipped away and the next higher dilution was then offered to the subject, the procedure continuing until a solution was tasted. In fact it was found advisable to check claims of ability to taste a particular solution by giving the subject a small amount of the next strongest solution. If the subject is mistaken there is little or no difference between the two solutions, whereas if he or she is really able to taste the solution specified the next solution will taste much stronger. This check helps to avoid extra sorting tests.

It was found that the pilot survey subjects, who were students, were very quick to become bored and fatigued in the full Harris and Kalmus tests. Since the main survey work was to be done with children it was necessary to modify the procedure in some way. It was decided to retain the thirteen solutions, but to decrease the number of cups used in the sorting test.

In the present 8 cup test the numbers of cups containing PTC or water are fixed and equal. There are 70 possible combinations when sorting 8 cups into four groups, therefore the probability of the correct combination being found by chance is 0.014. If six cups are used with equal numbers of PTC and water the probability of error is 0.05, while the use of six cups with the numbers ranging from 2 to 4 in each category reduces the probability of error to 0.02. However if five cups are used with either two or three in each group the probability of the right combination being chosen by chance is 0.05.

It was decided that the loss of accuracy contributed by the use of five cups in the test would be compensated by the increase in speed in the test as a whole. Since a check was included prior to the sorting test to see whether the subject was able to taste the next strongest solution it was unlikely that error of more than one dilution would occur. The combination of PTC and water containing cups was decided at the interview by reference to a table which had been prepared from a random number table. The cups were labelled A to E, and sequences of five numbers were taken from the random number tables and placed in columns A to E. Odd numbers were assigned to be PTC containing cups, and even numbers were to contain water. Sequences with five odd or even numbers, or four numbers in one category and one in the other, were rejected.

2R.7 Statistical Handling of PTC Data

There is a tendency in most work in PTC tasting to divide each population into two groups; tasters and non-tasters. This data is then treated by a simple two by two contingency table. When the PTC data results from the use of crystals, paper or a single solution, this is the only procedure that can be used, however when the Harris and Kalmus technique is used the data is divided into 14 classes (13 solutions and non-tasters of solution 1). In this case it is possible that merely to divide the whole distribution into two classes at the antimode will result in a loss of information.

It was decided to investigate whether a larger contingency table (2 x 11, 12 or 13) could help clarify the situation. Various results of PTC tasting from different authors and different populations were compared using this method. It was found that in several comparisons the populations were shown to be significantly different when a large contingency table was used, but when the 2 x 2 table was used there was no such difference. Further investigation of reports of PTC surveys showed that Das and Mukherjee (1964) and Das et al (1963) had used a 2 x 9 contingency table. Das and Mukherjee had also used a 't' test on the mean thresholds of the populations, but this method is not to be recommended in view of the non-normal distribution of taste thresholds. More recently Kaplan and co-workers (1964) used the Kolmogorov-Smirnov and the Mann Whitney U test as well as a 2 x 2 contingency table in handling their PTC data. It was decided to use 2 x 2 contingency tables for data split at the antimode, and the Kolmogorov-Smirnov test in handling the whole 14 class distribution. The Kolmogorov-Smirnov test was also used because it has a basic advantage over the large contingency table which in use dealing with data that has an underlying continuity. The Mann Whitney U test, which is a ranking test, was not attempted owing to the large size of the sample and the very large number of ties in the sample.

The antimode of a PTC taste threshold distribution is not always clearly defined. Kalmus and Maynard Smith (1965) have produced a complex formula for determining the best point of separation of the two classes. In practice the numbers of subjects found in the antimodal classes are so small as to make these calculations seem too exacting. Sunderland (1966) divides his antimodal class (PTC Soln. No: 4) in half and adds the resulting figures to the taster and non-taster groups. In the present survey it had been expected that the antimode could lie approximately between solutions 6 and 7, but from inspection of the data it was found to lie between solutions 3 and 4.

2S - ABO Secretor Trait

2S.1 History and Discovery of ABO Secretor Trait

The presence of the ABO system antigens in human saliva was first discovered by Yamakami in 1926. However it was not until 1930 that it was discovered that a proportion of the population did not secrete these antigens. It was shown by Schiff and Sasaki that the ability to secrete the ABO antigens in the saliva was inherited independantly from the ABO system and was a Mendelian dominant (Race and Sanger 1968).

It was concluded by Freidenreich and Hartmann that the ABO antigens occurred in two distinct forms. One form is alcohol soluble and is present in all the tissues but the brain. This form is not influenced by the secretor gene. The second form is Water soluble. It is not present in the serum or the red cells but occurs in the body fluids and organs of an ABO secretor (Race and Sanger (1968).

The presence of the ABO system antigens in saliva is established by testing the saliva for its ability to inhibit the appropriate ABO antisera. For instance saliva containing the B antigen would inhibit Anti-B. Inhibition of the anti-serum is tested by the addition of the appropriate red blood cells to a mixture of antisera and saliva. This meant that there was an initial difficulty in establishing the presence of an antigen in the saliva of O blood group secretors, as human sera with anti-O properties is very rarely found. However it was later found that anti-O sera could be produced from a variety of sources including sera from immunized goats, chickens and rabbits, human pseudomucinous ovarian cyst fluids of group O individuals, eel sera and extracts of certain plants. (Harris 1966).

It is now considered that a locus not associated with the ABO locus controls the production of the common precursor of both the A antigen and the B antigen. This precursor substance, H, is modified by the genes of the ABO locus to produce antigen A in blood group A, antigen B in blood group B and both A and B in blood group AB. In group O persons the precursor substance H remains unchanged as the only antigen, and a certain proportion of H antigen is also present in all the other blood groups. The proportion of H antigen present in the AB blood groups may be very small (Race and Sanger 1958).

In view of the presence of H antigen in all blood groups it is possible to divide a population into secretors and non-secretors by testing for the secretion of H. This method will tend to confuse the secretors of AB with the non-secretors, but as this group form a very small proportion of the total it is possible to admit this error. It is also possible to screen the whole population group by testing for H only, and then retest the non-secretors of H for secretion of A and B.

2S.2 Preparation of Anti-Sera

It was hoped to obtain enough saliva from each subject to enable the sample to be tested for A, B and H secretion. Full testing was possible only in the pilot survey samples as the majority of the samples in the main survey were inadequate. In the pilot survey testing anti A and anti B were obtained from the local Blood Transfusion Centre.

Anti H is now commonly prepared as a saline extract of

Ulex europaeus seed. There are various methods of extraction. Boorman and Dodd (1966) suggest that 1 gm of seeds is ground in a pepper mill and then left in an automatic shaker for one hour. The resultant mixture is centrifuged and the supernatent is used as anti-H. This is the basic method of Boyd and Shapleigh (1954). Flory (1966) prefers to incubate the *Ulex* seed in buffered saline for one hour and then cool it for 18 hours before centrifuging.

When the Boorman and Dodd method was tried out it was found very difficult to obtain a clear extract as there appeared to be a persistant form of emulsion in the supernatent. Dr. R.B. McConnell of the University of Liverpool was contacted and asked to advise. He very kindly provided full details of the procedures that he used, both in preparing the *Ulex* extract and in taking the saliva samples.

It was advised that the anti-H should be extracted by means of freezing and thawing the ground-up *Ulex* seeds in saline several times. This method proved to give a much clearer anti-H extract. Since it was necessary to store the prepared *Ulex* extract at -20°C it was found convenient to make 20 or 30 cc of the extract at one time and then divide this into small 5 ml bottles. This meant that only one small bottle needed to be unfrozen for any batch of testing and thus the rest of the extract was undisturbed.

In preliminary experiments the saliva samples were collected by means of giving the subjects ordinary acid drops to suck in order to promote the flow of saliva. This method was suggested by the regional Blood Transfusion Centre when they were consulted about the methods to be used. In this case the saliva was simply collected into a test tube. It was found that some samples obtained in this way contained a large proportion of citric acid from the acid drop, which had the effect of darkening the blood cells when they were added during the test. It was decided that it was inadvisable to use this method of collecting saliva, and the remaining samples were collected by means of the subject merely dribbling the saliva into the test tube.

It was found that the students in the pilot survey were quite willing to provide saliva samples of several ccs. However in the main survey the schoolchildren were rather reluctant to provide more than 0.5 cc of saliva, and many were unable to provide more than a small quantity of froth. Most appeared to feel most embarrassed at the request, though it was emphasized that this was a scientific experiment and not a question of manners.

2S.3 Preparation of Saliva Samples

As soon as the sample was collected it was put into a wide necked 16 fl oz thermos flask which was half filled with Dri-Kold solid CO_2. It was found that this procedure froze the saliva within seconds, even before any froth or bubbles had settled.

In order to kill any bacteria that might be present in the sample and to stop enzyme activity, it was necessary to boil the saliva samples for ten minutes (McConnell 1968, Race and Sanger 1968). This procedure was carried out at the base laboratory, the samples being transported back from the field in their frozen state. The test tubes of saliva were allowed to unfreeze partially at room temperature for 10 minutes and then placed in a boiling water bath for ten minutes. The initial unfreezing was to allow the frozen froth to settle into fluid. In the case of the very small samples it was necessary to note the original volume of the sample and replace fluid lost by evaporation. Normal 0.9% saline was used as a replacement, though it is possible that this could tend to raise the final osmotic pressure of the sample to be hypertonic to the red blood cells used in the testing. It was felt that a hypotonic solution would give rise to more problems.

After 10 minutes boiling the samples were removed from the water bath and allowed to cool. Since the samples were originally collected into centrifuge tubes it was now possible to centrifuge the samples without any transfer between tubes. This was an advantage in view of the small size of many of the samples. The samples were centrifuged hard for five minutes using a small bench centrifuge. In most cases this gave a clear supernatent with the debris of dead cells, food particles etc forming the plug. The supernatent of each sample was then transferred to a small plastic Luckhams tube for storage. The tube was labelled with the reference number of the subject and then plugged with cotton wool. The tubes of saliva extract were stored at -20°C until they could be tested. All the preparation of the saliva was carried out on the same day that they were collected. The saliva extract samples were stored in the deep freeze for periods up to three months, but McConnell (1967) has stated that samples will keep for up to a year at $-20^{\circ}C$.

2S.4 Testing of Saliva Samples

When it was decided to include the secretor trait in the survey it was thought advisable to obtain a practical demonstration of the techniques to be used. The local Blood Transfusion Service were willing to demonstrate the techniques that they used for this testing. They suggested that a 'tile technique' should be used in the present survey. Two drops of undiluted anti-serum and four drops of the saliva extract were put into a small test tube together and allowed to stand for 10 minutes. Then one drop of the mixture was put onto a white tile with a drop of concentrated red cells of the appropriate blood group. If the cells agglutinated this showed that the subject did not secrete the antigen that was being tested for. Three tubes were set up for each saliva sample, one with anti-H, one with anti-A and one anti-B. These mixtures were tested with O, A and B cells respectively. In addition to the test samples it was necessary to include three controls with saline in place of the saliva samples and also to run known secretor and non-secretor samples as a check.

This method was tried out with a small number of trial samples, but it was found difficult to judge the agglutination as this was often not marked. There was also a problem in that the tile tended to dry out before any positive result was obtained. It was therefore decided that more accuracy would be obtained by using a 'tube technique' involving the addition of the red blood cells to the extract/antiserum mixture in the test tube.

Race and Sanger (1968) suggest that saliva extracts should be diluted by half with saline and used with the appropriate dilution of anitserum that gives a good macroscopic reaction. Boorman and Dodd (1966) suggest that it is usually unnecessary to dilute Ulex extract as its normal strength is appropriate for testing undiluted saliva. In a study of secretion in Brazil, Palatnik et al (1969) used undiluted saliva and Ulex extract and also dilutions of both saliva and Ulex extract by a half. McConnell (1967) recommended using dilutions of a half and a quarter for the saliva extract, and diluting the antisera according to prior trials of its strength.

In the present survey it was decided to use both undiluted saliva extract and a 1.2 dilution of the extract in saline. It was found that both the undiluted Ulex extract and a 1.2 dilution of the extract in saline gave macroscopic agglutination, though the diluted extract required longer to produce this. Thus four tubes were set up for each sample, two containing diluted saliva extract and two undiluted extract. The undiluted Ulex extract was added to one of the tubes of undiluted saliva extract and one of the half strength tubes. Similarly the diluted Ulex extract was put into the other two tubes. Four drops of each of the two constituents were used in all cases. Where lack of saliva extract prevented all four tubes from being made up the undiluted saliva extracts were given priority.

The extracts were mixed and then allowed to stand at room temperature for 30 minutes. This time interval is recommended by McConnell (1967), Boorman & Dodd (1966) and Boyd and Shapleigh (1954), though Race and Sanger (1968) only advise leaving the mixture for a few minutes. At the end of the 30-minute period 4 drops of 5% red blood cells of Group O were added to each tube. The mixture was then gently shaken and allowed to stand for two hours at room temperature.

In the pilot survey it was also possible to test the saliva extracts for A and B antigens in addition to H. A parallel procedure was used in these cases, and A and B saline controls were included. In the main survey only the secretion of H was tested. Every batch of samples was accompanied by standard Group O secretor and non-secretor salivas and a control with saline instead of saliva extract.

The red blood cells used in the survey were obtained from the local Blood Transfusion Centre. In the pilot survey and the earlier experiments some blood was provided by the investigator herself but unfortunately she was group A and therefore could not use her own blood for the main survey. The blood cells provided by the Blood Transfusion Centre were washed three times in normal saline and re-suspended in saline to give a concentration of approximately 5%.

When the blood, anti-H and saliva extract mixture had stood for two hours the results were read. The tubes were first tapped gently to disturb the cells which had fallen to the bottom of the tube. It was then noted whether any macroscopic clumping could be seen in the liquid. If this was present the tube was scored as a positive agglutination. In doubtfull cases a portion of the contents of the tube was withdrawn by means of a Pasteur Pipette and placed on a white tile for closer examination. If there was any doubt the mixture was examined under a microscope.

2S.5 Interpretation of Results

It was accepted that some weak secretors might not be able to inhibit the undiluted *Ulex* extract. This was found to be the case in that some subjects showed agglutination in the undiluted H and dilute saliva tube but not in the others. Such cases were scored as secretors. Cases where the four tubes showed inconsistent results were retested if the volume of the saliva extract allowed, but if this was not possible they were rejected.

2T - Laterality

2T.1 Causes of Laterality

From early times it has been noted that a minority of the human population preferred to use their left limbs for certain activities. The Old Testament contains reference to a large group of left handed warriors who were most efficient in battle.

Many theories have been put forward to explain this difference. Clark (1957) quotes the primitive weapon theory of Thomas Carlyle and the centre of gravity theory of Buchanan. Carlyle was of the opinion that right handedness had been developed because primitive man tended to protect his heart with his left arm and used his spear with his right. Buchanan thought it possible that handedness was decided by displacement of the centre of gravity of the body. It has also been postulated that education is the deciding factor in handedness, and a psychological explanation of left handedness as a manifestation of negativism and revolt against the norm was advanced at one time.

2T.2 Cerebral Dominance and Laterality

It has been established that there is some link between laterality and cerebral dominance. Annett (1964) has suggested that handedness is very closely linked with cerebral dominance, both being determined by a single gene pair. She suggests that the dominant homozygote is right handed and his speech is controlled by the left hemisphere whereas the recessive heterozygote is left handed and has speech in the right hemisphere. Heterozygotes may use either hand and may develop speech in either hemisphere, though normally they will resemble the dominant homozygotes. The theory is supported by the evidence of Landsell (1962) who found that seven of nine right brained patients were left handed.

However some workers dispute the closeness of the association of cerebral dominance and handedness. Goodglass and Quadfase (1954) believe that the two factors are not directly linked, nor does one determine the other. They point out that the frequency of right-brained persons is far lower than that of left handed persons. They also note that 53% of left handed persons have speech in the left side of their brain as evidenced by the effects of brain damage.

Roberts (1955) suggests that cerebral dominance is not linked with either handedness or eyedness, though it is possible that cerebral function is less differentiated in the left handed subject. Palmer (1964) argues that there may be little functional difference between the cerebral hemispheres as there is little morphological difference between the right and left side of the body. He suggests that the two hemispheres start with equal potentiality but one gains control of speech. However handedness is not determined by the same cerebral area as speech and so this theory may not be applicable to such motor functions, though he accepts an association of cerebral dominance and handedness. Palmer also notes that increased percentages of left and mixed handed persons are found among epileptics, stutterers and those with reading disabilities.

2T.3 Development of Laterality

Roos (1935) has suggested that the position of the foetus in the last few weeks of pregnancy could affect handedness by restricting movements of one side of the body. Another possibility was that the basic metabolic rate of the mother could affect the child's handedness as the children of hyperthyroid mothers might be expected to be more active foetuses and therefore to use both hands more. However Roos found that this association was not present, nor was birth weight associated with handedness, though there were more right handed children who had above average birth weights.

Swanson and Benton (1955) found that knowledge of right and left increased with age until the child was seven, and there was then a decrease in the number of correct responses in the seven to nine year old. Harris (1957) found that the proportion of right handed increased as children increased in age, though the preferred eye and foot did not alter. In a study of ten 3 year olds Brown (1962) noted that half used one hand more frequently and eight out ten used one hand for skilled activities.

2T.4 Heredity of Laterality

In a family study Falek (1959) found that families where the mother was left handed and the father right had an increased proportion of left handed children both when motor tests (such as grip strength, and tapping), and when simply activity tests (writing, dealing cards) were used. All the other family combinations, including both parents left handed, had between 11% and 18% left handed children, but the left mother - right father families had 43% to 50% of the children left handed. Falek only included 45 families in the survey so it is possible that the results were affected by the sample size.

Chamberlain (1928) studied 2177 American college students and their families. She found that families with one or both parents left handed had 17.3% of their children left handed, as compared to only 2.1% of the offspring of two right handed parents. In this survey also the sex of the left handed parent affected the frequency of left handed offspring. Only 9.7% of the children of left handed fathers were themselves left handed, in comparison with 13.8% of those with left handed mother.

Trankel (1955) stated that handedness is probably controlled by a single dominant recessive pair of alleles, where the dominant gene produces right handedness and environmental and other genetic factors also affect the manifestation of handedness. Alternatively he suggests that right hand dominance might be a purely environmental effect with left handedness caused by an allele which is only effective when homozygous. Trankell's first theory is similar to that of Annett (1964) who also suggested that a single gene pair was responsible. In a further study Annett (1967) found that the proportion of right mixed and left handed persons in a number of different samples fitted the Binomial distribution. This might be taken as evidence for the single gene pair theory.

Rife (1950) noted that 50% of the offspring of two left handed people were left handed as compared to 6% of those with right handed parents and 17% of those from mixed marriages. He also found that more left handed twins had had left handed relatives than right handed twins, and suggested that handedness is a multifactorial character (1940). Merrell (1957) also noted the increased frequency of left handed offspring of left handed parents, and notes a similar effect in family data on ocular dominance. Where both parents have a dominant right eye 23.7% of the children are left-eyed. In mixed marriages 43.9% of the children are left-eyed and where both parents are left eyed 54.2% of the children are also left-eyed.

2T.5 Heritability of Laterality Factors

It has not been possible to find any estimates of the heritability of various aspects of laterality. The reason for this lack may be the high rate of discordance in MZ twins for laterality characteristics. Rife (1950) found 22.3% of MZ twins were discordant for handedness, and Shields (1962) found 17.0% discordant. Newman (1927) suggested that there were two kinds of handedness in MZ twins, the basic genetic type and an epigenetic type produced by the effects of twinning. He suggests that asymmetry or mirror imaging in twins may be shown in all grades of severity ranging from complete situs inversus viscerum to hair whorl and handedness differences. He also noted that these reversals were most frequent in the more dissimilar MZ twins. Price (1936) also suggested that many factors including asymmetry could produce difference in MZ twins. In a later paper Newman (1940) puts forward the view that asymmetrical twins are the result of late divisions of the embryo and that differences between them are due to the embryo having begun to differentiate before division.

Helweg-Larsen (1947) describes a pair of MZ twins with complete inversion of the viscera and agrees that they have probably resulted from the late division of a zygote. Warkany et al (1955) describe a MZ twin pair who had mirror image abnormal canine teeth. However Torgersen (1950) examined 270 cases of situs inversus viscerum in Norway and found that there was no greater incidence of twinning or left handedness in this group than in the general population. Only 6.9% of this group were left handed. He concludes that visceral inversion and laterality differences are due to similar factors but both factors are independant of twinning.

2T.6 Assessment of Laterality

In the majority of surveys of laterality information is collected on the subjects' hand, eye, foot or ear preference in performing a number of simple tasks. Some rely on a questionnaire survey in which the subject writes down his preferred side in response to a series of questions. The Harris Tests of Lateral Dominance (Harris 1958) include a series of ten hand preference questions. Subjects are asked to state which hand they would use to throw a ball, wind a watch, hammer a nail, brush their teeth, comb their hair, turn a door knob, hold a rubber, use scissors, cut with a knife and write. All these actions are unimanual and therefore preferances are easily recollected by the subject. However it was felt that certain of these activities, such as winding a watch, using scissors and turning a door knob, might be determined by environmental factors. In order to wind a wrist watch with the left hand it is necessary to turn it so that the figures on the face are upside-down. Most scissors are designed for use by the right hand, which must affect their use by the left handed person, and door knob positions vary. The remainder of Harris Test involves the subject in carrying out practical tasks.

In large scale surveys a questionnaire is often the only possible method of obtaining data. Chamberlain (1928) collected information on students and their families by this method. Annett (1967) collected laterality data from seven groups by means of a questionnaire asking which hand was used to write a letter, to use a racquet, strike a match, use scissors to cut paper, thread a needle, deal cards, hammer a nail, hold a toothbrush, unscrew a jartop, hold the top of a broom when sweeping and hold the top of a shovel to move sand. In the last two activities both hands are used, and it is uncertain which plays the dominant role. The motive power of the broom or shovel is provided by the top hand, but the skilled direction of the instrument is a function of the lower hand. Rife included shooting marbles, bowling and whittling in a series of laterality questionnaires (1940, 1950, 1953). Falek (1959) used a questionnaire to sort out interesting families for further investigation. In the original survey Falek asked for the subjects' laterality preferences in writing, dealing cards, drawing, sweeping and turning a door key. Selected families were used in a practical test during which they demonstrated to original activities and also their use of a spoon, striking a match, cutting bread and threading a needle. Motor tests such as grip strength and tapping speed were also carried out.

One of the most extensive laterality questionnaires was found in a survey by Humphrey (1951). He used 20 activities, twelve unimanual and eight bimanual. Besides writing, throwing and the usual unimanual activities, he includes the use of a razor and a screwdriver. Presumably this would not be an electric razor as less skill is required for this type than the safety razor. The ten bimanual activities included use of knife and fork and the swinging of a cricket bat as well as the more frequently tested jartop unscrewing, striking a match, threading a needle, dealing cards, sweeping and raking. He also noted foot and eye performances.

The alternative to using a questionnaire is to provide the subjects with the necessary apparatus and ask him or her to demonstrate how they would perform the task. This involves the observer being present when the survey is carried out and usually this means transporting the subjects to suitable standardized conditions. It was noted that Falek (1959) used a questionnaire in a preliminary survey and then extended this to a practical test later.

In dealing with small children it is often more informative to observe their activities than to ask questions. Brown (1962) observed 3-year-olds at play and noted their hand preferences. In 1937 Johnson and Davies devised an elaborate sequence of instructions that could be given to seven-year-olds. An observer watching the child was able to score his laterality in performing 40 separate actions, involving only normal school procedures such as rubbing out, colouring, filling a pen, etc. They found that the correlation between repeated test scores was + 0.91. Benton and Menelee (1957) used a test battery of 35 items to determine handedness.

The Harris test includes a section on eye dominance and one of foot dominance. Foot dominance is assessed by checking the subject's preferred foot for kicking and stamping. Harris includes both monocular and binocular tests in his eye dominance section. The monocular tests involve the use of a Kaleidoscope toy, a telescope and a toy rifle. In each case the eye used by the subject is noted. The binocular tests are more complex but the result is an assessment of the subject's eye dominance.

Černček (1964) used 17 tests of laterality including some not reported in any previous survey. These included tying a knot in string, drawing a circle and a square when blindfolded and making the knot when adjusting a necktie. Černaček also used physical differences such as variations in nail formation between the two sides and suggested that the temperature of the body of the dominant side was higher. He also states that the ability to close one eye alone is more developed on the dominant side.

In a comprehensive investigation of laterality in 330 Glasgow children Clark (1957) used a battery of 19 tests. Nine of the tests were concerned with handedness. These were writing, unscrewing a jartop, throwing, reaching up for an object, picking up beads, simultaneous writing, rotating arms alternately, tapping speed and a specialized drawing reversal test, the van Riper test. To assess foot dominance Clark used three tests. The children were asked to kick a ball, to hop and to step out from standing with both heels against the wall. Eye dominance was tested by asking the children to look at a peep show, down a cylinder, through a hole in a card and through a cone. Clark also tested ear dominance. The children were asked to listen to a sound in a box and to a stop watch. A further test was made by making a sound behind the child and observing in which direction he or she turned. Barker (1967) and Bryden (1963) found laterality differencies in auditory perception.

2T.7 Grip Strength Testing

Grip strength may be tested by means of an instrument known as a dynamometer. (Jones 1947, Burke et al 1953, Anderson and Cowan 1966). This test is included in the Harris tests. Since it was possible to borrow such an instrument from the Applied Psychology Department it was decided to run a series of tests to see how well left and right dominant subjects could be sorted by this method.

The instrument used was a Stoelting Dynamometer, which gives grip strength in pounds. Ten subjects were used, and grip strength readings were taken for both hands of each subject on two successive days.

The subject was instructed to hold the dynamometer at arm's length by his or her side. A count-down was then given: Prepare to squeeze, 3, 2, 1, squeeze, 1, 2, release. The subjects were previously told to hold the 'squeeze' for the count of two. The reading was noted and then the procedure was repeated until five readings for each hand had been obtained. One minute was allowed between each attempt to allow for recovery of the muscles.

In fact it was found that the left and right hands of an individual were only significantly different in half the cases. Some of the subjects obtained significant differences on the first day but not on the second, and vice versa. Only five subjects obtained the same results on both days. It was decided that hand grip was too complex a variable to be used in a multi-trait survey such as the present one.

2T.8 Laterality Classification in the Present Survey

At the time of the pilot survey it had been decided to classify hand dominance for writing, dealing cards, throwing a ball, using a racquet, hammering a nail and threading a needle. Eye dominance was defined by observing which eye the subject used to look through a kaleidoscope provided. The hand traits were determined either by a questionnaire procedure or, if the subject seemed doubtful, by asking him or her to mime the activity. Miming of laterality activities was used in a survey by Belmont and Birch (1963).

It was found that the subjects needed less time for this part of the survey than had been expected, and so another bimanual activity, unscrewing a jartop, was included. For this test a small jar was provided and the subject was asked to take off the top. Foot dominance was also included. The subjects were asked their preferred foot for kicking and were also asked to mime their actions if a spark had fallen on a rug and they wished to stamp it out. This gave a total of ten laterality activities; seven for hand dominance (4 unimanual and 3 bimanual), two for foot dominance and one for eye dominance.

2U - Metric Variables

2U.1 Measurement of Height and Weight

Measurement of the heights and weights of various population groups must be one of the most common exercises in human genetics. In view of this, increasingly accurate methods have been devised for measuring these variables. A survey such as the present one would, in ideal circumstances, use a portable stadiometer for measuring height (Stone and Jones, 1968). In this case such an instrument was not available. In the pilot survey a standard anthropometer with a sliding arm was used to measure the subjects' height. It was found difficult to keep this instrument in a perpendicular position when measuring the subject, though the method suggested by Hertzberg et al (1963) was used. In this method the subject stands erect looking directly forward while the anthropometer is held vertically behind him with its base on the level of his feet. The sliding arm of the anthropometer is then brought down to touch the subject's scalp, and his stature is recorded. The problem in the present survey was that the short stature of the investigator (158 cm) meant that the majority of the subjects in the pilot survey were taller than her. This meant that in order to read off the height of the subject accurately the investigator had to add to her height by means of a sturdy box, while at the same time steadying the anthropometer and maintaining it in a vertical position. It was felt that this procedure would lead to errors, particularly as the investigator was working alone and so could not rely on another observer being present to check the position of the anthopometer. An attempt was made to fix the anthopometer by clamping its base in a number of laboratory clamp stands, but this procedure appeared to add to the instability of the apparatus. Since it was expected at this time that the survey subjects would be adult it was necessary to modify the measuring method so that persons of greater height than the investigator could be measured with accuracy.

It was decided to utilise a schools height measure designed for attachment to a wall. This took the form of a squared bar of wood 4 ft in length marked off into centimetres and a sliding marker with a ball bearing mechanism which allowed it to be placed at any point on the bar. The University workshops modified this apparatus by adding a free standing lower portion to the original bar, this being of the appropriate length such that the readings were still true heights. This free standing base was attached to the original portion by means of two butterfly nuts, so that it was possible to dismantle the apparatus for transporting. In addition to a cross piece the base had a third leg which could be folded away for travel. This height measuring apparatus was tested in comparison with the anthropometer and found to give comparative results. When used in the field the height measuring apparatus was set up and then its verticality was checked by means of a plumb line. The subject was then asked to remove his or her shoes and stand in front of the measuring apparatus with his or her feet together and head up. The sliding marker was then brought down to touch the subject's head and the stature was read off the vertical scale to the nearest 0.1 cm.

It is felt that this method of measuring height is comparable with that used by Scott (1961) in measuring London school-children. Scott used a similar measuring rod attached to the wall, which also had a block that was slid down to touch the head of the subject. The method used by Knott and Meredith (1963) appears to have been similar. Most surveys appear to take 0.1 cm as the point of division of the scale (Scott 1961, Knott and Meredith 1963, Stone and Jones 1968, Malina et al 1970), but Dann and Roberts (1961) measured students to the nearest half-inch.

A weighing machine is of necessity a more complex piece of apparatus than a height measure. The necessity to provide portable apparatus in the present survey was a problem. It would have been possible to use each school's own scales which were kept in the medical rooms, but it was felt that variation between different scales would lead to considerable errors. It might have been possible to adjust all the scales to a standard weight, but this would have involved transporting standard weights to the schools. It was felt that it would be simplest to use an ordinary personal 'bathroom' type scales of good quality since such an instrument could be transported to each school in turn. The scale purchased was the Salter 209 Precision Personal Weigher, which is claimed by the manufacturer to have an accuracy of $\pm$ 1 part in 560. The kilogram version of this machine was used, and the subjects' weight was noted to the nearest 500 g ($\frac{1}{2}$ kilo). Subjects were weighed wearing indoor clothes but not shoes or blazers. In the calculations involving weight 1.5 kg was subtracted from the original machine result to allow for the weight of the subject's clothing.

Stone and Jones used a beam type scale in weighing their sample of students as did Knott and Meredith. Both Stone and Jones and Scott (1961) took weight to the nearest 0.1 kg (100g) but Dann and Roberts (1961) only took weight to the nearest 1.0 lb. Although it would have been preferred to use a more formal beam type scale it was found that the Salter scale gave reproducable results, and it is anticipated that its results are accurate.

2U.2 Measurement of Foot Length and Width

It was decided to include measurements of the foot in order to extend the anthropometric section of the project. The foot was chosen as an easily accessible part of the body. It had been hoped that subjects would be willing to take off their socks or stockings, however it was found during the pilot survey that most were not prepared to do this for reasons of cleanliness. In the case of females there was the further complication of tights and in some cases tights and trousers. It was decided to measure the subjects' feet with their socks or stockings in place as preliminary trials showed that the errors involved in this procedure were small. A discussion was held with a member of Clarke's staff who was about to undertake a foot measurement survey for his firm. It was discovered that they proposed to measure foot size with the subject still wearing his hose, but to note the thickness of the socks in each case. Both Hertberg et al and Stone and Jones measured the subjects' feet without covering.

Blais et al (1956) used a single wooden caliper to measure childrens' feet. In a survey for the Shoe and Allied Trades Research Association, Manning (1955) used a wooden stick marked out in shoe sizes, but he also drew round the foot to form a plan and then measured this plan in inches. The Clark's foot survey proposed to use a variety of measuring methods including drawing a plan of the foot, measuring its length by means of a marker stick, measuring its various girths by measuring tape and photographing the foot from five different views. In a full anthropometric survey Hertzberg et al (1963) recommended the use of a specially prepared foot board provided with both vertical and horizontal scales.

It was decided to follow the method of Stone and Jones (1968). These workers measured foot length and foot width at the joint by means of a modified commercial foot measuring device as used in shoe shops. This device, the Brannock Foot Gauge is obtainable in both adult and childrens' sizes. In this case the adult size gauge was purchased as the original aim in the survey was to study adults. It is probable that an adult size foot gauge would have been required even if the school survey had been planned from the outset, as the growth of the foot tends to be completed before the rest of the body. (Blais et al, 1956).

The Brannock foot measure was converted to give two centimetre measure scales; one for length and one for breadth. This work was carried out by the University of Loughborough workshops who had done the conversion for Stone and Jones. Measurements were taken with the subject sitting on an average height chair with the foot placed flat upon the ground. The modified foot measuring device was placed on the ground and the subject was instructed to place his or her foot in it so that his or her heel fitted the heel cap. The device was positioned so that the subject's knee joint formed an angle of 90° approximately. Only the left feet were measured as the modification of the Brannock device limits its use to this foot.

Each of the measurement scales had a sliding marker which was used to indicate the length of breadth of the foot. When the foot was placed in the measuring device it was checked that the heel was touching the heel cap and that the first metatarsal-phalangeal joint was touching the right hand side plate. The marker of the length scale was then moved down to touch the end of the longest toe, and the length of the foot at this point was noted. The width marker was then adjusted so that it touched the left side of the foot at the fifth metatarsal-phalangeal joint, and the joint width of the foot was read off.

2U.3 Indices of Height and Weight

Variations in height and weight may indicate either overall size differences or else different types of body build. In order to clarify this situation it is usual to calculate an index of body build combining both these factors. The most commonly used index is the Ponderal Index Height/$\sqrt[3]{\text{Weight}}$. In this index the variables can either be measured in inches and pounds or centimetres and kilograms. The answers obtained using the two scales are directly related. Ponderal indices are used extensively by Sheldon (1964) and Hertzberg et al (1963). There has recently been a considerable volume of work upon the relative fertility of men of different ponderal index. (Heath 1954, Damon and Nuttal (1965) Dann and Roberts noted the ponderal indices of students in a Welsh college.

Though the ponderal index is frequently calculated some workers have proposed that other indices would provide more information. Khosla and Lowe (1967) note that a simple weight/height index underestimates obesity whereas the ponderal index overestimates obesity. They suggest that weight/Height^2 provides a satisfactory index as this variable is independant of height but is closely associated with body weight. These findings were confirmed by Evans and Prior (1969) on two Polynesian groups. It was noted by these workers that this obesity index was correlated with adiposity as measured by skinfold thickness. They preferred to multiply the single index by 100, thus giving the final equation:

$$\text{Obesity Index} = \text{Weight} \times 100/\text{Height}^2$$

It can be seen that the ponderal index differs from the obesity index in all its dimensions

$$\text{Ponderal Index} = \text{Height} / \sqrt[3]{\text{Weight}}$$

This obesity index is also used by Billewicz et al (1962). Kelmsley et al (1969) have suggested that the ratio of observed weight to a standard weight scale would give an estimate of relative adiposity.

It was decided to include both the ponderal index and the obesity index in the present survey. Both were calculated from the height and weight data by the computer program. It was decided to test the two indices for their independance, and also to assess their association with the other metric characteristics under study. As has been previously stated the computer program is only able to accept metric variables as whole numbers. The metric variables were therefore multiplied by ten before being fed to the computer. The program that was written allowed for this change by dividing the metric data entries by ten to recover the original values. The subtraction of 1.5 kilos from the weight of each subject also took place within the computer. All these data modifications took place before any values for the indices were calculated.

3 RESULTS

3A - Introduction to Results Section

In view of the large bulk of data collected in the present survey it has been felt that it was advisable to segregate the tables of raw data and results in a series of appendices, rather than scattering them through the text. It has therefore been decided to quote the relevant table numbers referred to in each paragraph of the results. In tabulating the results it was felt that tables specifying only frequencies by sex could legitimately be omitted, as the data appears in the remaining tables.

3B - Background Data

3B.1 Geographical Background - Basic Data

It was found that the sample had unexpectedly strong Midland origins. Of the total U.K. sample 64.2% had both their parents born in the Midlands and a further 25.5% had one Midland and one English or British. It will be noted therefore that the English parentage group had in fact 78.4% of its members with one Midland parent and similarly 57.3% of the British parentage group had one Midland parent. Dividing the U.K. sample into parentage groups it was found that there were 64.2% Midland, 18.6% English and 17.2% British subjects in the sample. As the survey proceeded it was found that it would have been possible to divide the Midland subjects into those born in Birmingham and those not. However it was at this stage too late to reclassify the data.

In the grandparents' birthplace data it was found that 42.2% of the sample had all 4 grandparents born in the Midlands, and a further 12.4% had 3 Midland grandparents. There was also 23.3% of the sample with 2 Midland grandparents. There was a noticeable association of parents' birthplaces and grandparents' birthplaces. Of those with two Midland parents, 82.3% had 3 or 4 Midland grandparents, of those with two English parents 79.2% had 3 or 4 grandparents born within the same area, and 94.6% of the grandparents of those with both parents British were born within that area. In the case of those with one Midland and one other parent the greatest frequencies are found in the grandparents group of two Midland and two English or two British. (tables E3, E8)

3B.2 Social Class Background - Basic Data

The Social class distribution is approximately symmetrical, with the peak at Social Class III (semi-skilled). The distribution of the social classes in employed males in the Registrar General's Midland Region in 1961 was 3.5% SC I; 12.9% SC II; 54.3% SC III; 21.1% SC IV and 8.3% SC V. In the present survey the proportions of SC I and II approximate the 1961 figures being 3.7% for SC I and 14.3% for SC II. There is however a slight excess of SC III (59.8%) and a slight deficit in SC IV and SC V (19.2% and 3.0%). This probably represents the bias inherent in the voluntary nature of the survey in that a larger proportion of the least able families either declined to be involved in the survey or else merely lost the official consent form. There was also a greater problem of absenteeism in the non-selective schools so it is possible that this may have added some slight bias. (table E1)

3B.3 School Type-Basic Data

Of the total U.K. sample 54.4% came from grammar schools and 45.6% from non-selectives. This proportion in no way represents the proportion found in the total Birmingham population of the appropriate age group, as the grammar school children are in fact in a minority. The object of the survey was to obtain approximately equal sized samples for comparison, but the secondary modern sample proved more difficult to obtain than the grammar school sample. (table E2)

3B.4 Sex - Basic Data

It was hoped to obtain approximately equal numbers of boys and girls in the sample, but for some reason there was rather better co-operation from girls' schools than from boys'. At the final count the total sample contained 46.7% males and 53.3% females. (table E1)

3B.5 Associations Between Background Factors

Since there are four main background factors (SC, School, Parentage and Sex), there are six possible associations between the factors. All these possible associations were investigated. It was found that there was no significant difference in the total sample with regard to social class, school type or parental origin, however significant associations were found in the other three comparisons.

School type was found to be significantly associated with the social class background in the total sample and in the male and female samples separately. In the grammar schools sample 28.1% of the children came from SC I or SC II homes; 56.9% came from SC III and 15% from SC IV and V. Only 5.5% of the non-selective school children came from SC I or II. There was a rather larger proportion of SC III children in the non-selective school sample, 63.4%, and there were 31.1% from SC IV and V homes (table E4 a-c).

There was also a significant association of school type and parental origin in the total sample. On separation of the sexes it appears that this association is contributed by the female sample alone, as there is no significant association in the male sample. However the Chisquare heterogenity test was applied and the heterogenity between the sexes is not significant. The major difference between the female samples from the two types of school is their proportion of English and British girls. In the Grammar school sample there are 20.3% English and 11.9% British but in the secondary modern sample there are 13.5% English and 26.2% British. (table E6 a-c)

Social Class is significantly associated with parental origin in the total sample, but examination of the data with sexes separated shows that this association comes from the female sample. In this case there is significant heterogenity between the male and female samples and so they cannot be combined in this association. The difference seems to arise from an excess of the English group in the SC I and II. In the English group 38.5% belong to SC I and II whereas only 12.1% of the Midland and 7.8% of the British are so classified. (table E5a-c)

3C - Pilot Survey

3C.1 Inclusion of Pilot Survey Results

It is proposed to include the pilot survey results in a separate section since it is accepted that the small size and specialized nature of the sample prevents their being of general application.

3C.2 Composition of Sample

A total of 50 students was collected. Of these 41 were male and 9 female. Their ages ranged between 19 and 27. All were either undergraduate or postgraduate students at the University of Aston, or the Colleges of Art and Commerce. For the purpose of testing the computer program for the original survey the subjects were arranged as husband-wife pairs without regard to their actual sex.

In terms of geographical origins 70% of the students had both their parents born in England, 8% had noth parents born in the U.K. and 18% had one parent in each category. In the sample 54% had all four grandparents born in England and a further 32% had all four born in Britain.

The social class distribution of the pilot survey sample was skewed in the direction of the classes of greater prestige. Ten percent of the student sample had SC I parents; 42% had SC II parents. Only 38% were placed in SC III and 8% in SC IV. There were no students with parents in SC V, though one was unable to give details of parental occupation. (table 4Da)

3C.3 Pilot Survey Laterality Results

Only seven tests of lateral dominance were used. In the pilot survey group 16% wrote left-handed and 30% dealt cards without a right hand preference. Only 16% used a racquet with their left hand, but 24% used this hand for throwing a ball and 20% used it for holding a hammer. Left eye dominance was noted in 38% of the sample and a total of 30% used their left hand in threading a needle. (table 4Dc)

3C.4 Pilot Survey Non-Metric Results

All the variables that are not either laterality tests or metric variables are included in this section. In the classification of vision defects 62% wore glasses either part time or full time, and five of the male had colour vision defects. Light eyes were noted in 54% of the sample, 38% had mixed colour eyes and 8% had dark eyes.

Only two subjects had red hair, though 56% had slightly reddish hair. Straight hair was found in 38% of the group, 26% had slightly wavy hair and 36% had deeply waved hair. Widow's Peaks were present in 18% of the persons examined, and a further 22% had an intermediate type hairline.

Examination of ear lobe types proved that 44% of the sample had free ear lobes, 28% had intermediate type ear lobes and 28% had attached or fused lobes. All the females lacked a chin cleft, but 24% of the total sample possessed some chin indentation. Freckles were only present in 32% of the student sample.

In the hand type variables it was noted that 68% of the group had long ring fingers, 20% had long index fingers and in the remaining 12% the ring and index finger were of equal length. Mid-digital hair was present in 70% of the pilot survey group. The small size of this group makes the frequencies of the different finger types with hair somewhat abnormal. Only 18% had MDH 1, 30% had MDH 2 and 10% had MDH 3, and the remaining 12% had MDH 4.

It was possible to determine the ABO secretor status of all the persons in the pilot sample. In the case of the secretors it was also possible to give a tentative blood group on the basis of their salivary secretion. In the total group 24% were non-secretors and 76% secretors. Within the secretor group 43.2% were Group O, 48.6% Group A and 8.1% Group B. No AB Secretors were found. Tasters of PTC were found to form 84% of the group when the PTC data was divided at the antimode between solution 3 and 4.(table 4Db)

3C.5 Pilot Survey Metric Results

The mean height of the males in the pilot survey was found to be 176.0cm, the mean of the females was 160.5am. The mean weights measured in kilograms were 71.2 for males and 58.4 in females. In the males the mean foot length was 26.4cm and the mean foot width was 9.4cm. The comparable measurements for females were 23.8cm foot length and 8.5cm mean foot width. The males had a mean ponderal index of 42.6 and the females mean was 41.4. (table 4Dd)

3C.6 Classification of Somatotype

The ponderal indices were converted to the inches/lbs scale and then the corresponding somatotypes were obtained from Sheldon's table (Sheldon 1954). It was found that many of the ponderal indices had more than one possible somatotype, and that the total distribution of somatotypes in the sample could be varied considerably by taking the most ectomorphic, the most mesomorphic or the most endomorphic ratings in each case. It was decided that it was not therefore worthwhile to continue with this part of the investigation.

3D - Eye Colour

3D.1 Basic Eye Colour Results

The proportions of the various eye colours found in the sample varied from 40.9% for blue to nil for dark brown. The light eyed group, which was made up of 6.4% blue-grey and 40.9% blue-eyed persons formed 47.3% of the total. The mixed eye colour group formed 35.5% of the total. Grey-green eyes were most common in this colour group, being found in 13.9% of the subjects, and there was a further 12.2% of the sample with grey-green eyes with a brown centre. Only 0.5% of the sample were classified as green-eyed, and 8.9% were grey-eyed. The remaining 17.3% of the sample belonged to the dark-eyed group. If this group 3.1% had grey-brown eyes, 4.4% had green-brown eyes, 5.7% had light brown eyes and 4.1% had mid-brown eyes.

There was no significant differences in eye colour between the two school types, though there were slightly more light eyed subjects in the non-selective school. In the grammar school sample 46.1% were light eyed but in the secondary modern group there were 48.5% light eyed. Although there were no significant differences between the social class groups the results would seem to indicate a slight excess of light eyed children in the manual group, and possibly in the professional group. The greater proportion of light eyed subjects was found in the manual group where they formed 55.1% of the total. In the professional group 49.0% were light eyed but only 43.1% of the middle class were placed in this category.

Although there was a considerable sex difference in the proportions of the different colour groups, this difference was not significant. Both sexes had approximately the same proportion of dark eyed persons, 17.2% of males and 17.3% of females. However in the male sample 51.3% had light eyes and 31.5% had mixed eyes, but in the female sample the comparable figures were 43.7% light and 39.0% mixed.

In comparisons of the differences between the various parental origin groups it appears that the proportion of light-eyed persons in the Midland group is less than in the English and British groups. This difference occurs in both the male and female samples but it is not significant in either sub-sample or in the total sample. In the Midland males 49.4% are light eyed, but 53.6% of the English and 56.6% of the British share this classification. The Midland females have only 35.5% light eyed as compared to 49.1% of the English and 53.4% of the British. (tables F1a,b,c)

Eye Colour and Hair Colour

See Section 3G.8

Eye Colour and Colour Vision

See Section 3E.2

3D.2 Eye Colour and Freckles

It was found that there was a significant association of freckles and eye colour in the total sample. This association was not significant in the male and female samples when separately analysed, but the same trend could be seen in both sub-samples. In general the presence of freckles was found to be associated with light eyes, and conversely the absence of freckles was associated with dark eyes. In the group that had no freckles 42.8% were light eyed, but 46.2% of the group with slight freckling and 58.4% of the heavily freckled group were light eyed. The highest frequency of dark eyed persons was found in the non-freckled group where 21.6% belonged in this class. Only 10.8% of the heavily freckled group and 15.6% of the lightly freckled were dark eyed. (table I3abc)

3D.3 Eye Colour and Mid-Digital Hair (MDH)

Nid-digital hair was found to be significantly associated with eye colour in the female sample but not in the male sample or the total sample. In the light eyed females 43.9% had no MDH and the comparable figure for the dark eyed females was 43.6%, but only 38.6% of the mixed eye colour girls had no MDH. However 21% of the light eyed females had one finger with MDH as compared with 18.5% of the mixed and 16.4% of the dark eyed girls. The greatest frequency of girls with two fingers with MDH was found in the mixed eye colour group, where 31.5% of the total were placed in this category. In the light eyed group only 13.7% had two fingers with MDH as did 21.8% of the mixed class. So few of the subjects possessed four fingers with MDH that these results have been added to those for three fingers with hair. The light eyed female group appeared to contain an excess of girls with MDH on three or four fingers. This class formed 23.7% of the total, whereas in the mixed eye colour group only 15.3% were so classified, and in the dark eyed group 19.2% had hair on three or four fingers. (tableI4abc)

3E - Colour Vision Defects

3E.1 Total Frequencies and Background Data

As previously stated (2H.11) only the males were tested for defects of colour vision. This reduced the total UK sample size to 279. Of these 279, 8.2% had some defect of colour vision. This 8.2% defective composed of 6.5% deutan defect, 1.4% protan and 0.3% unclassified defect.

There were no significant differences between the two school types, though there were slightly more subjects with colour vision defects in the selective schools. In the grammar schools 8.8% of the pupils had colour defects but in the non-selective schools 7.6% were defective.

In the social class groups there was no definite trend in any direction, and the differences between groups were not significant. In the group from a professional background 9.3% were colour defective, as compared to 7.5% of the middle class and 10.2% of the manual class.

There were no significant differences between the groups of different parental origin, though again there were small differences. Only 7.3% of the Midland sample were colour defective, but 8.3% of the English group and 10.1% of the British group fell into this class. (tables F2a-d)

3E.2 Colour Vision Defects and Eye Colour

It was found that colour vision defects were associated with eye colour to a significant degree. Of those with normal colour vision 53.5% were light eyed, whereas only 26.1% of those with defects fell into this category. The remaining part of the difference occurred mainly in the mixed eye colour group. In the normals 29.7% had mixed eye colour, but 52.2% of the defectives belonged to this group. There were also rather more dark eyed persons in the defective group, 21.7% as compared to 16.8% of the normal group (table I5).

3E.3 Colour Vision Defects and Chin Types

A significant association was found between colour vision defects and the absence of a cleft in the chin. In the subjects with normal colour vision 37.1% had some degree of indentation of the chin, but only 13.0% of the defectives possessed this characteristics (table I6).

3E.4 Colour Vision Defects and Ocular Defects

If a Chisquared 2x2 contingency test is applied to the association of colour vision defects and ocular defects a significant result is obtained. However on closer inspection it is found that the test is not theoretically valid as it uses an expected value less than 5 (Siegel 1963). Despite this it is worth noting that 34.8% of those with defects wore glasses, as compared with only 12.5% of those with normal colour vision (table I7).

3E.5 Colour Vision Defects and Mid-Digital Hair

From the present survey results it seems possible that a significant association between mid-digital hair and colour vision defects might be found in a larger sample.

In the present small sample this comparison was of borderline significance ($x^2 = 3.74$, if $x^2 = 3.89$ $p = 0.05$). The proportions of the different mid-digital hair types in the two groups appeared to be very considerably different. In general the boys with defects of colour vision tended to have more fingers with mid-digital hair present. Of those with normal colour vision 40.2% had no mid-digital hair, 21.5% had one finger with hair, 25.4% had two with hair and 13.1% with hair on three or four fingers. The comparable figures for colour defectives were 17.4% with no mid-digital hair, 13.0% with one finger, 43.5% with two and 26.1% with hair on three or four fingers. (table I8)

3F - Ocular Defects

3F.1 Total Frequencies and Sex Differences

In the total sample 10.4% were wearing glasses at the time of the interview, and a further 11.1% stated that they wore glasses for certain activities. There was a very significant difference between the sexes in this character. In males 10.0% wore glasses full time and 4.3% wore them half time, whereas in females 10.7% wore glasses full time and 17.0% wore them part time. The difference between the sexes lies in the proportion of the sample wearing glasses part time; approximately equal proportions wearing glasses full time. If the sexes are compared with regard to the proportion wearing glasses either part-time or full-time there is still a significant difference (see tables F3a-c).

3F.2 Ocular Defects and School Type

The proportion of children with ocular defects was quite markedly different in the two types of school. In the grammar school sample 13.3% wore glasses full time and 11.4% wore them part-time, but in the non-selective schools only 7.0% wore glasses full time and 10.7% wore them part-time. However this difference is only significant at the 0.05 level, and this significance is not found if the two sexes are considered separately (see tables F3a(iv)-c(iv))

3F.3 Ocular Defects and Eye Dominance

It was found that there was a highly significant association between the possession of a dominant right eye and the need to wear glasses in males. Of those with a dominant left eye only 5.7% wore glasses part-time or full-time, in comparison with 18.3% of the right eyed subjects. These two characters were also significantly associated in the sample as a whole, but although there was no heterogenity between the sexes by chisquare test it would seem from the data that the association was only present in males. The comparison for females alone gave a probability of 0.7 (see tables 6abc).

3F.4 Ocular defects and Skin Type

In both sexes there was a significant association of absence of freckles and the wearing of glasses. Of the total sample only 6.9% of those with freckles wore glasses full-time and 9.9%

part-time, the comparative figures being 16.1% full-time and 18.2% part-time for those without freckles. In the males 19.8% of those without freckles had ocular defects in comparison with 9.9% of the freckled boys. Similarly in the female sample 34.4% of the non-freckled wore glasses, but only 22.7% of the freckled. (table I9abc)

3F.5 Ocular Defects and Finger Length

In the female sample finger length was found to be significantly associated with ocular defect. In the group of females whose ring finger was longer than their index finger only 19.4% wore glasses either full- or part-time. In the remainder of the sample 31.8% wore glasses. This association was not found in the male sample. (table I 10abc)

Ocular Defects and Colour Vision Defects

(See section 3E.4)

3G - Hair Colour

3G.1 Introduction to Hair Colour Results

In the main hair colour was measured both by comparison of the subject's whole head of hair with a standard range of hair samples, and by use of the Munsell colour range. It is convenient to report the results of both these methods in a single section as they closely related. In this report hair darkness and hair redness refer to the hair sample comparison and hue, chroma and value refer to the Munsell classification.

3G.2 Interrelationships of Hair Colour Variables

In investigating the relationships between the Munsell specification and the visual scale it was decided to include the non-UK and non-European groups in the general total sample comparisons involving the Munsell system. This was really an exercise to compare the two methods of measurements, rather than a racial investigation.

The comparison between hair redness and hair darkness showed a significant association of the two variables in both sexes and in the total UK sample. As might have been expected there was a deficit of definitely red haired persons in the darker haired groups. Among the females all those with definitely red hair were classified as having light brown hair. In the males 30.8% of the definitely red haired were fair haired, 58.8% had light brown hair and the remaining 15.4% had mid brown hair. In the total sample 15.4% of the red haired were fair, 76.9% were classified as light brown and 7.7% as mid brown.

Hair darkness was significantly associated with both value and chroma in the total general sample. Of the fair hair sample only 11.7% were classified as value 1 or 2, and 54.3% had value 4 or greater. In the group with dark brown hair only 5.2% had value 4 or greater, and 94.8% had a value classification of 1 or 2. Similarly in the comparison of chroma and hair darkness only 5.8% of the fair haired group had chroma readings of 1 or 2 as compared with 93.1% of the dark brown haired group. None of the dark brown haired subjects had chroma classification of 4 or over in comparison with 55.4% of the fair haired group.

Hair redness was also significantly associated with chroma and value in the general total sample. Of the definitely red haired group 44.5% had chroma readings of 4 or greater but only 5.7% of those with non-red hair had this classification. Value readings of 4 or more were found in 85.2% of the definitely red haired group in comparison with only 14.8% of the non-red haired group.

Chroma and value were significantly associated with each other in the total general sample. In this case only Hue YR 10 was included as it was felt that inclusion of the very red samples might confuse the picture. As there were only 17 samples classified as YR 7.5 it was not possible to carry out a chroma by value comparison in this group. All of those with chroma 1 or 2 were classified as value 1 or 2, but none of them were placed in the value 4 or more class. None of those samples classified as value 1 or 2 obtained a chroma value of five or over, but 75% of the value 4 or over had chroma readings of five or more.

In consideration of the association of hue and hair darkness and redness it was not possible to use chisquare tests owing to the small number of subjects with YR 7.5. However it was found that the majority of those with hue YR 7.5 were classified as haing light brown hair on the darkness scale. In the total general sample 2.91% of the fair haired, 4.98% of those with light brown hair and

1,0% of those with mid brown hair were classified as hue YR 7.5. In the hair redness comparisons it was found that none of the non-red class had hue YR 7.5 and only one (0.2%) of the slight red class was not classified as hue YR 10.0. However in the visually definite red class 59.3% were given the hue classification of YR 7.5 and 40.7% were classed as YR 10.0. (tables I 21a-g)

3G.3 Hair Colour and Sex Differences

All four measures of hair colour were found to be significantly associated with sex. In the case of hair darkness the male group contained 19.1% with fair hair, 37.1% with light brown hair, 38.8% with mid brown hair and 5.0% with dark brown hair. In the females the comparable results were 15.8% fair, 48.6% light brown, 33.1% mid brown and 2.5% dark brown. Hair redness was found to be associated with sex, though the proportions of persons with definitely red hair were similar in both sexes. Of the males, 4.8% had definitely red hair, 77.5% had slightly red hair and 19.7% had non-red hair. The female group contained 4.1% with definitely red hair, 83.9% with slightly red hair and 12.0% with non-red hair. The results for value showed that 56.0% of the males had value 1 or 2 as compared to 41.2% of the females. Value 3 was present in 17.1% of males and 10.6% of females, and values of 4 or over were found in 19.9% of males and 48.2% of females. The chroma results also showed the sex difference,with the males having less colour intensities. In the male sample 62.9% had a chroma result of 1 or 2, 32.6% had chroma of 3 and 12.4% had chroma of 4 or more. However in the females only 36.9% had chroma 1 or 2 hair, while 40.8% had chroma 3 and 22.3% had a chroma of 4 or more. (tables F4a-b)

3G.4 Hair Colour and School Type

School type was not significantly associated with any of the hair colour variables in the total sample, though there was a slight trend towards lighter hair among the non-selective school pupils. In the grammar school sample 16.7% had fair hair, 40.9% had light brown hair, 38.1% had mid brown hair and 4.3% had dark brown hair. The comparable results in the nom-selective school sample were 18.0% fair, 46.0% light brown, 33.1% mid brown and 2.9% dark brown. However the males showed a significant association of hair darkness and school type in the computer analysis but this result was found to be invalid owing to the table totals being too low for use of the chisquare test.

In the male selective sample 16.3% had fair hair, 34.0% light brown hair, 42.9% mid brown hair and 6.8% dark brown hair, as compared with the non-selective group where 22.3% were fair, 40.5% light brown, 37.4% mid brown and 3.1% dark brown. The female sample showed less variation, though there were more subjects with light brown hair in selective schools and more with mid brown hair in the non-selective schools. (see tables F4a(iv) - c(iv))

In the hair redness comparisons there was no significant difference between the various proportions of hair redness in the two school types. However there appeared to be a trend towards a greater number of definitely red haired persons in the non-selective school type. Only 3.1% of the selective group had definitely red hair in comparison with 5.9% of the non-selective children. The proportions of persons with slightly red hair were similar in the two groups, there being 79.3% in the selective group and 80.9% in the non-selective group, but there was a greater proportion of persons with non-red hair in the selective group than the non-selective group. The results for non-red hair were 17.6% in the grammar schools and 13.2% in the secondary schools. (tables F4d(iv)-f(iv))

The chroma results showed great similarity between school types. Among the males the grammar school sample contained 54.9% with chroma 1 or 2, 31% with chroma 3 and 14.1% with chroma 4 or over. The comparable figures in the non-selective males were 55% chroma 1 or 2, 34.9% chroma 3 and 10.1% chroma 4 or more. The female grammar school sample was made up of 37.4% chroma 1 or 2, 40.4% chroma 3 and 22.2% chroma 4 or more, whereas the non-selective girls contained 36.2% chroma 1 or 2, 41.5% chroma 3 and 22.3% chroma 4 or over. (tables F4g(iv) - i(iv))

Value was not found to be associated with school type in either sex. In the males the grammar school group contained 64.1% with value 1 or 2, 16.2% with value 3 and 19.7% with values over 3. The secondary modern male group consisted of 61.5% value 1 or 2, 18.3% value 3 and 20.2% with value more than 3. Among the females 42.1% of the grammar school group had value 1 or 2 as compared with 40.0% of the non-selective group. Value 3 was found in 11.1% of the grammar school girls and 10% of the secondary modern girls, while values of over 3 were found in 46.8% and 50.0% of the two samples respectively. (tables F4j(iv) - l(iv)

3G.5 Hair Colour and Class Group

Social class (in the form of class groups) was not found to be associated with any of the four hair colour variables. Hair darkness showed little class group variation. In the professional group males there were 15.1% with fair hair, 49.1% with light brown hair, 33.9% with mid brown hair and 1.9% with dark brown hair. The proportions in the middle class group were 20.6% fair, 33.1% light brown, 40.6% mid-brown and 5.6% dark brown. In the manual males 20.8% had fair hair, 34.0% had light brown hair, 37.7% had mid brown hair and 7.5% had dark brown hair. The same slight trend to an increasing proportion of dark brown hair from professional to manual groups is found in the female sample. Here the professional group contained 12.5% fair haired girls, 39.6% with light brown hair, and 47.9% with mid brown hair. No professional group girls had dark brown hair. Only 1.7% of the middle class girls had dark brown hair, in comparison with 5.5% of the manual group. The remaining hair darkness classes were found in similar proportions in the middle and manual girls. Fair hair was present in 16.3% of the middle class and 15.1% of the manual groups, while light brown hair was found in 51.7% of the middle class and 45.2% of the manual group. Subjects with mid-brown hair made up 30.3% of the middle class girls and 34.2% of the manual girls. (see table F4a(ii) - c(ii))

In the hair redness results there was little difference in the proportions of persons with definitely red hair in the three groups. Among the males 5.6% of the middle class and 3.8% of both the professional and manual groups were definitely red haired, while in the females no professional group girls were definitely red haired in comparison with 4.5% of the middle class and 6.8% of the manual group. Non red haired persons made up 20.8% of the professional males group, 18.1% of the middle class group and 24.5% of the manual group. In the females 14.6% of the professional group had non-red hair in comparison with 10.11% of the middle class and 13.7% of the manual group. Correspondingly slightly red hair was found in 75.5% of professional males, 76.3% of middle class males and 71.7% of manual males; the comparable figures for females being 85.4% for both professional and middle classes and 79.4% for the manual group. (tables F4 d(ii) - f(ii))

Consideration of the chroma results appears to show a trend towards an excess of chroma 1 or 2 in the manual or middle class males, but in the females the excess of chroma 1 or 2 is found in the professional group. In the professional males 49.0% had chroma 1 or 2, 39.2% had chroma 3 and 11.8% had chroma over 3. The comparable figures for the middle class males were 55.9% chroma 1 or 2, 31.0% chroma 3 and 13.1% chroma over 3, while in the manual males 56.8% had chroma 1 or 2, 29.5% had chroma 3 and 13.6% had chroma more than 3. However in the females the professional group showed an excess of chroma 1 and 2, 53.3% as compared with 34.9% in the middle class and 33.3% in the manual group. There were corresponding deficits of both chroma 3 subjects and those with chromas over 3 in the professional group. Only 31.1% had chroma 3 hair as compared with 41.9% of the middle class and 42.4% of the manual group, and subjects with chroma over 3 were found to comprise 15.5% of the professional group, 23.3% of the middle class group and 24.2% of the manual group. (tables F4g(ii) - i(ii))

In the value results there was no notable difference between the proportions of value classes in the male social class groups. The professional class contained 58.8% value 1 or 2, 17.6% value 3 and 23.5% with value over 3, while the middle class group was made up of 64.8% with value 1 or 2, 16.6% with value 3 and 18.6% with value greater than 3. The manual male group contained 61.3% with value 1 or 2, 20.5% with value 3 and 18.2% with a value greater than 3. The female sample appeared to show a possible association between increasing hair colour value and increasing social class prestige. In the professional girls 57.8% had hair with value 1 or 2, as compared with 40.1% of the middle class group and 34.8% of the manual group. There was little variation in the percentage with value 3, the comparable figures being 6.7% in the professional girls, 11.6% in the middle class and 9.1% in the manual group. As would be expected there was an increasing proportion of hair values over 3 in inverse relation to the proportion of value 1 and 2. In the manual group girls 56.1% had values over 3 as compared with 48.3% of the middle class and 35.6% of the professional girls. (tables F4j(ii) -l(ii))

3G.6 Hair Colour and Parental Origin

In the comparisons of hair colour variables with parental origin it was found that this characteristic was significantly associated with hair redness, but not with the other three hair variables. There were some variations in the proportions of the hair darkness classes in both sexes though these were not significant. In the Midland males 21.5% were fair haired as compared with 17.9% of the English and 11.1% of the British. The remainder of the Midland sample was composed of 35.6% with light brown hair, 37.9% with mid brown hair and 5.1% with dark brown hair. Of the English sample there was 37.5% of both light and mid brown hair and the remaining 7.1% had dark brown hair. The British male group contained 42.2% with light brown hair, 44.4% with mid brown hair and 2.2% with dark brown hair. Some differences were also noted in the female sample. Fair hair was found in 17.2% of the Midland group but only in 12.7% and 13.8% of the English and British groups respectively. The British female group contained 56.9% with light brown hair in comparison with 47.1% of the Midlanders and 45.5% of the English. Mid brown hair was found in 41.8% of the English girls but only 33.3% of the Midland group and 24.1% of the British. There were no girls with dark brown hair in the English group, but this colour class formed 2.5% of the Midland group and 5.2% of the Britsh group. (tables F4a(iii) - c(iii))

The hair redness comparisons were significant in the total sample though not in the single sex comparisons. Among the males definitely red hair was present in 4.5% of the Midland group, 3.6%

of the English and 6.7% of the British. The main difference however was in the relative proportions of nom-red and slightly-red haired subjects in the three origin groups. Non-red hair was found in 30.7% of the English males as compared with only 17.5% of the Midland group and 15.6% of the British group. Similarly only 66.1% of the English had slightly red hair, whereas 78.0% of the Midland sample and 77.8% of the British sample had slightly red hair.

The variation in the female sample appeared to show the same pattern. Here definitely red hair was present in 3.9% of the Midland girls, 3.6% of the English and 5.2% of the British. Non-red haired girls made up 20%of the English sample in comparison with 13.8% of the British and 9.3% of the Midland group. Slightly red hair was found in only 76.4% of the English sample as compared with 86.5% of the Midland group and 81.0% of the British. (tables F4d(iii) - f(iii))

The chroma results showed no clear pattern of variation in either sex. Chroma 1 or 2 was found in 52.4% of the Midland boys, 59.6% of the English and 60.0% of the British. Chroma 3 subjects formed 33.5% of the Midland male sample, 28.7% of the English sample and 32.5% of the British sample. The remaining percentages,which were made up of those with chroma results greater than three, were 14.0% for the Midland group, 10.6% for the English group and 7.5% for the British. There was rather more variation among the females. The Midland female group was made up of 37.8% chroma 1 or 2, 39.9% chroma 3 and 23.3% with a chroma result over 3. Among the English females the comparative results were 34.0% chroma 1 or 2, 49.1% chroma 3 and 17.0% over chroma 3, while in the British females 36.4%

had chroma 1 or 2, 40.0% had chroma 3 and the remaining 23.6% had chroma results over 3. (tables F4 g(iii) - i(iii))

Munsell values appeared to show a slight association with parental origin though these differences were not significant, and the value distribution differed in the two sexes. In the males 70.0% of the British had hair colours of value 1 or 2 as compared with 61.0% of the Midland boys and 63.8% of the English. The proportions with value 3 were moderately similar in all three groups, there being 15.9% in the Midlands, 17.0% in the English and 22.5% in the British. Those with values greater than 3 formed 23.2% of the Midland group, but only 19.1% of the English and 7.5% of the British. Among the females there was less variation; value 1 or 2 subjects made up 42.0% of the Midland group, 37.7% of the English group and 41.8% of the British group. Value 3 was found in 11.4% of the Midland girls, 11.3% of the English girls and 7.3% of the British. Both the English and the British female groups contained 50.9% with hair values greater than 3, as compared with 46.6% of the Midland group. (tables F4j(iii) - l(iii))

3G.7 Hair Colour and Hair Form

Hair form was found to be significantly associated with hair darkness, hair redness, chroma and value. However the sex involved in the significant association varied. Hair darkness and hair form were found to be significantly associated in the female sample and in the total sample, but not in the males. In the females it appeared that straight hair was associated with fair hair colour. In the straight haired females 19.0% had fair hair in comparison with 17.7% of those with wavy hair and only 2.0% of those with deeply waved hair. Among the males 21.8% of the straight haired were fair, as were 17.9% of those with slight waves and 15.6% of those with deep waves.

Hair redness was only significantly associated with hair form among the males. In this case 13.3% of those with deeply waved hair had definitely red hair, in comparison with 2.4% of those with slight waves and 3.6% of those with straight hair. Among the females definitely red hair was noted in 4.0% of those with deeply waving hair. The proportion of those with non-red hair also differed in the males. The straight haired group contained 23.6% with non-red hair, in comparison with 3.3% with deeply waved hair and 18.7% of slight waves.

Chroma and hair form were found to be significantly associated in the total sample and the female sample. In consideration of the chroma results for the female sample it is noted that the proportion of straight haired girls in the colour group increase with increasing chroma. In the group with chroma 1 or 2 only 33.3% were straight haired but in the group with chroma 4 or more 49.3% were classified as straight haired. Similarly the proportion with deeply waved hair appears to decrease as chroma increases. Only 7.5% of the girls with chroma result of 4 or more had deeply waved hair in comparison with 13.1% of those with slight wave and 20.7% of the straight haired. A comparable variation in the frequency of straight haired individuals was noted in the male sample though this was not significant. Among the males 33.3% of those with chroma 1 or 2 were straight haired, as were 45.1% of those with chroma 2 and 53.3% of those with hair chroma results over 3.

Hair form was only significantly associated with value in the total sample. The same trend was detected in both the single sex samples, but the relationship of the two variables was far from simple. There was an excess of straight haired persons in the group with value 3, and a deficit of persons with slightly wavy hair in this same group. Straight hair was found in 52.7% of those with value 3 in comparison with 43.3% of those with values over 3 and 54.0% of those with value 1 or 2. Slightly wavy hair was only present in 35.1% of the value 3 group people, but such subjects made up 46.8% of the value 1 or 2 group and 45.3% of the group with value over 3. (tables I 14abc)

3G.8 Hair Darkness and Eye Colour

As was expected hair darkness and eye colour were significantly associated but eye colour was not associated with Munsell value or chroma. This association was present in both the male, female and total samples. It was noted that light eyes tended to be associated with light hair and dark eyes with dark hair. In the males 79.3% of the fair haired persons had light eyes, but only 38.5% of those with dark brown hair had light eyes. Among the females 70.0% of those classified as fair were light eyed, as were 31.0% of the girls with dark brown hair. Only 3.6% of the fair haired males and 2.0% of the females had dark eyes but 23.7% of the dark brown haired males and 22.9% of the comparable females were dark eyed. (tables I 2abc)

3G.9 Hair Redness and Skin Types

Skin type was significantly associated with hair redness in the total sample and in the single sex samples. There was an increased proportion of definitely red haired subjects among those who were classified as heavily freckled. In the males there were no cases possessing definitely red hair and no freckles. Of the slightly freckled males only 3.3% had definitely red hair in comparison with 16.1% of those who were heavily freckled. One female without freckles had definitely red hair (0.7%), but in the lightly freckled females 2.5% had definitely red hair in comparison with 15.5% of those with heavy freckling. (tables I 15abc)

3G.10 Hair Redness and Ear Type

In the total sample a significant association between hair redness and ear type was noted. From the results it appears that the distribution of hair redness colour classes in the free ear lobe group differed from that in the other ear types. In the free ear lobe group 19.8% had non-red hair in comparison with 12.2% in the intermediate group, 14.4% in the attached lobe group and 11.9% of the fused lobe group. The free lobe group also contained the second largest proportion of definitely red haired persons, a total of 5.8% in comparison with 4.6% in the intermediate group, 2.2% in the attached group and 6.0% in the fused group. This meant that the proportion of persons in the free lobe group with slightly red hair was lower than the proportion in the other three ear lobe types. Only 74.5% of the subjects with free ear lobes possessed slightly red hair in comparison with 84.0% of the intermediate type, 83.5% of the attached type and 82.1% of the fused type. (tables I 16abc)

3G.11 Hair Darkness and Hair Line

Hair darkness was shown to be significantly associated with hair line in the male sample and in the total sample but not among the females. The distribution of the variation was found to be without clear pattern. In the males there was an excess of fair haired persons lacking a widow's peak or irregular hairline. However there was an excess of persons with dark brown hair and an intermediate hairline while no person was found with dark brown hair and a widow's peak. Of those males with a level hairline 21.6% were fair haired in comparison with 15.7% of those with an irregular hair line and 15.0% of those with a definite widow's peak. The proportion with light brown hair were similar in all the classes, but there was an excess of subjects with mid brown hair and definite widow's peaks. The widow's peak group of males contained 48.3% with mid brown hair, whereas the intermediate group contained only 31.4% and the level hair line group only 37.7%. As previously stated there were no dark brown haired males with widow's peaks, and only 2.4% of the level hairline group had dark brown hair, but 19.6% of the intermediate hairline males had this colour classification. In the female sample the trend towards an increased population of fair haired persons without widow's peaks could be seen. In the level hairline group 18.1% were fair haired in comparison with only 8.3% of the intermediate group and 11.6% of the widow's peak group. However there was no excess of dark brown haired subjects in the intermediate group, as in fact no subjects in this category were found. (tables I 12abc)

Chroma and PTC

(See section 3P.5)

Hair Colour and Weight

(See section 3S.10)

Chroma and Ponderal Index

(See section 3S.13)

Chroma and Height

(See section 3S.12)

3H - Pilot Survey and Preliminary Hair Colour Results

3H.1 General Discusssion of Preliminary and Pilot Survey Hair Colour Measurements

The main feature of the results of the reflectance values of the pilot survey hair samples and the preliminary survey hair samples was their low reflectance values. In the case of the pilot survey results the scale of the spectrophotometer was adjusted to gain accuracy in the reading, but this procedure was not possible in the case of the preliminary survey. There is therefore a large measure of possible inaccuracy in these readings, and this must affect the validity of the calculated indices.

3H.2 Reflectance Values Preliminary Survey

Duplicate readings of percentage reflectance were taken for all the hair samples at nine wavelengths ranging between 425mμ and 685 mμ . From these the average reflectance of each sample was calculated. As expected the majority of the reflectance readings showed an increase as the colour of the reflected light moved from the blue end of the spectrum to red. At 425 mμ the lowest reading was 2% reflectance, while the highest was 15.0%. The sample with the lowest reflectance remained at 2% up to 595 mμ , while the maximum reflectance value climbed from 18% at 485 mμ to 25.5% at 595 m . At 655 mμ the least reflective sample gave 2.5% while the most reflective gave 31.5%, and at 685 mμ the corresponding values were 3.0% and 36.0%.

When the total of the nine reflectance values is added together it is found that the sample with minimum reflectance scores 19.5, while the maximum reflectance sample scores 206.5. These values represent the extremes of the range of hair colour reflectance and it will be seen that the distribution of total reflectance scores is flattened and slightly skewed towards the darker end of the scale. (tables C1-10)

3H.3 Reflectance Values in Pilot Survey

The pilot survey hair samples were also measured at nine wavelengths, but owing to use of a different spectrophotometer the same points were not used. The minimum reflectance value at 420 mμ was 3.0%, but this fell to 2.3% at 440 mμ, 2.4% at 470 mμ, 2.3% at 500 mμ and 2.2% at 520 mμ. The maximum reflectance values ranged from 10.4% for 420 mμ to 27.6% for 660 mμ. This is a lower percentage reflectance maximum than that found in the preliminary results, but it must be realised that the preliminary sample was selected to include the extremes of hair colour. There is also a difference in the wavelength of the final readings which would contribute to this difference.

The total reflectances scores of the pilot survey samples range from 23.7 to 148.6. This is a narrower range than that present in the preliminary sample, but this is again explained by the selection of the preliminary sample for extreme hair colours. The distribution of total reflectance scores is again skewed towards the darker end of the scale, but in this case the distribution is less flattened than the preliminary survey distribution. (tables D5-14)

3H.4 Calculated Indices from the Preliminary Data

The results of the indices calculated from the simple reflectance data represent the usefulness of the index in dividing the hair samples into colour groups rather than measurement of colours. The R index was found to overestimate the proportion of red hair in the group, with 68.8% classified as red haired. However the version of the Gardner-MacAdam index gave a less extreme result with only 3.9% classified as red haired and 9.8% as red-brown. (tables C11 & 12)

3H.5 Calculated Indices from Pilot Survey

As with the preliminary data the object of the pilot survey hair colour investigation was to determine the most useful forms of the indices, using all possible combinations of reflectance readings. Only two of the pilot survey samples were visibly red, and so the relative scores of these two samples were compared with the non-red samples to give an indication of the efficiency of the indices. The pilot survey version of the Gardner-MacAdam index gave two samples of hair in the red-brown category (4%), while the remainder were classified as non-red. However one of the samples classified as red was in fact non-red visually, while one of those classified as non-red appeared strongly red.

It was possible to calculate four R indices, Of these it was found that those involving reflectance at 520 mμ gave an overestimate of the proportion of red hair in the population. By using formula R1 74% of the group were classified as red haired, while formula R3 have 54% of this category. Formula R2 classified only 12% as red haired, this included both the visually red samples but the remainder of the group were non-reds. Only 4 samples (8%) were classified as red by the R4 formula, but two of these were non-red. From these results it would seem that the R4 formula gave the best estimate of red hair frequency of an index, but this estimate was not accurate. (tables D15 - 19)

3H.6 and 3H.7 - see page 235a (overleaf)

3I - Hair Form

3I.1 Basic Frequencies of Hair Form Type

In the total UK sample 39.7% had straight hair, 44.4% had slightly wavy hair, 13.9% had deeply waved hair and 2.0% had curly hair. In view of the small percentage of curly haired subjects noted in the survey these persons have been included in the deep wave class for the remainder of the report. There was no significant sex difference in this trait. Straight hair was found in 39.6% of males and 39.7% of females. Slightly wavy hair was noted in 44.2% of males and 44.5% of females, while the remaining 16.2% of males and 15.8% of females had deeply wavy hair.

There was a significant difference in the frequencies of the various classes of hair type at the two types of school. This difference was only present in the total sample where it reached the 2% level of significance, but the same trend could be detected in the single sex samples. In basis there was an excess of straight haired persons in the secondary modern group. In the total sample 35.0% of the grammar school group were straight haired as compared to 45.2% of the non-selective sample. Slightly wavy hair was noted in 47.4% of the grammar school group but only 40.8% of the secondary modern children were placed in this category. The proportions of the two groups with deeply waved hair were more similar than the

3H.6. Tristimulus Values and Chromaticity Coordinates, Pilot Survey

As with the simple reflectance results the tristimulus readings were very low. For tristimulus X the range of readings was 2.5% to 18.9%, while the range for tristimulus Y was 2.4% to 18.4% and the values for tristimulus Z ranged from 2.6% to 8.1%. It was found that tristimulus Y was significantly correlated with the total darkness of the sample as measured by reflectance at 650mu. The chromaticity coordinates x and y were calculated, and it was found that the values for x ranged from 0.286 to 0.443, while the values of y ran from 0.317 to 0.401. These chromaticity coordinate values were plotted on a graph (see fig. 3, tables D20 - 24).

3H.7. Munsell readings of Pilot Survey Data.

The Munsell colour specification of each of the pilot survey samples was obtained. It was found that only the two visibly red samples had a hue of 7.5YR while the remaining samples were classified as 10YR. In the Munsell value classification 58% of the group were noted as value 2, while 28% had hair of value 3, 12% had value 4 and 2% value 5. The colour intensity (chroma) comparisons showed that 22% were classified as chroma 1, 50% as chroma 2, 12% as chroma 3 and 16% as chroma 4. (tables D25).

other two classes. Fourteen percent of the non-selective group were classified as having deeply waved or curly hair, but 17.6% of the selective sample shared this classification.

In the social class group comparisons a significant difference in hair form between classes was present in the total sample, though not in the single sex samples. There was a trend towards a greater proportion of persons with deeply waved hair in the professional groups. This could be noted in the single sex samples as well as in the combined sex sample. In the total sample deeply waved hair was present in 23.8% of the professional group as compared with 15.7% of the middle class group and only 11.5% of the manual group. The proportion of slightly wavy hair was approximately the same in all three social class groups, but the professional group showed a corresponding reduction in the proportion of straight haired persons. In the professional males 22.6% were put into the deeply waved hair class, as were 25.0% of the females. However it was in the female sample that the most striking differences in the proportion of straight haired subjects were noted. Only 22.9% of the professional females had straight hair, but this characteristic was noted in 42.8% of the middle class and 42.9% of the manual group.

There were no significant differences in the parental origin comparisons in this trait, but there were variations between the groups. The Midland sample contained the greatest proportion of straight haired persons; 42.7% in all. Only 33.3% of the English sample were straight haired, as were 34.9% of the British sample. There was also variation in the relative number of persons with deeply waved hair. Of the British group only 12.6% were placed in this category as compared with 16.3% of the Midlanders and 18.0% of the English. In the males only 4.4% of the British had deeply waved hair in comparison with 17.9% of the English group and 18.6% of the Midland group. (see tables F5abc)

3I.2 Hair Form and Foot Preference in Kicking

A significant association between hair form and foot preference in kicking was present in the male and total samples but not in the female group. In the females the proportions preferring to use their left foot or having no foot preference remained almost constant in the three hair form classes. In the straight haired girls 80.2% were right footed in comparison with 80.9% of those with slightly wavy hair and 81.6% of those with deeply waved hair. But in the male sample there was an increased frequency of left or mixed footed kickers in the deep wave group. Only 48.9% of this group were right footed, though 73.4% of the straight haired boys and 73.2% of those with slightly waved hair showed this foot preference. (see tables L8abc)

Hair Form and Hair Colour

(see section 3G.7)

Hair Form and Weight

(see Section 3S.8)

Hair Form and Height

(see section 3S.8)

Hair Form and Foot Width

(see section 3S.8)

3J - Hair Line Type

3J.1 Hair Line Type - Basic Results

It was found that 17.3% of the total UK population had a definite widow's peak, and a further 16.6% had an intermediate type hair line. There was a very significant sex difference in this trait. In the males 21.6% had definite widow's peaks and 18.3% had the intermediate type of hair line, but in the females the comparable figures were 13.6% with widow's peaks and 15.1% intermediate type.

A significant difference was also noted in the school type comparison. In the total sample 22.3% of the grammar school pupils had peaked hair lines and 16.7% were intermediate whereas only 11.4% of the non-selective school children had widow's peaks and 16.5% were intermediate. The same association is found to be significant in both the male and the female sub-samples. In the males peaks were present in 27.8% of the grammar school pupils but only 14.5% of the non-selective school sample. The proportions of the intermediate hair line type were similar in both groups, 17.0% of the grammar school boys and 19.8 % of the non-selective school boys being so classified. The female sample had a lower frequency of widow's peaks overall. The grammar school girls had 17.6% with peaked hair lines and 16.5% with the intermediate type, as compared with 8.5% widow's peaked and

13.5% intermediate type among the secondary modern school girls.

The social class groups did not differ significantly in their numbers of different hair line types, but there were considerable variations between the groups. Peaked hair lines were present in 30.2% of the professional class boys, but only 17.5% of the middle class and 22.6% of the manual background boys. The intermediate hair line was found in 9.4% of the professional males, 21.3% of the middle class and 20.8% of the manual group. In the female sample the differences were not so notable. In the professional class females 14.6% had peaked hair lines and 22.9% had the intermediate hair line type. The comparable results in the middle class females were 15.2% with widow's peaks and 13.5% intermediate, and in the manual group 9.6% had widow's peaks and 13.7% had intermediate hair lines.

Hair line was not significantly associated with parental origin either in the total sample or in the single sex sub-samples, though there appeared to be a deficit of individuals with widow's peaks in the English sample. The English males group contained 12.5% with widow's peaks and 7.3% of the English females shared this characteristic. In the Midland sample 23.7% of the males and 16.2% of the females had widow's peaks, and of the British group 24.4% of the males and 10.3% of the females were placed in this class. (tables F6abc)

3J.2 Hair Line and Mid-digital Hair

A significant association between hair line type and mid-digital hair was found to be present in the male sample. This association did not occur in the female sample. Though some tests of the total data also showed the association it would appear that this was due to the association in the males.

As in most associations including mid-digital hair, the situation is complex. In terms of the presence or absence of mid-digital hair it was found that 55% of those males with a widow's peak had no mid-digital hair. In the intermediate hair line group 31.4% had no mid-digital hair, and of those with a level hairline 34.7% lacked any MDH. When the number of fingers with MDH are considered further differences are noted. In the intermediate hair line group 31.4% have one finger with MDH, but only 15.0% if those with a definite peak and 19.8% of those with a level hair line are included in this class. Two fingers with MDH is a type found in 31.7% of the level hairline males, but only 17.6% of the intermediates and 20.0% of the peaked. Only 10% of those with widow's peaks have hair on 3 or more fingers as compared to 19.6% of the intermediate group and 13.8% of the level hair line group. (tables I 11abc)

<u>Hair Line and Hair Colour</u>

(see section 3G.11)

3K - Ear Lobe Type

3K.1 Ear Lobe Type Basic Results

There was a very significant sex difference in the frequencies of the different ear lobe types. In the males 43.3% had free lobes, 19.4% had intermediate lobes and 37.2% attached or fused lobes. Of the female sample only 32.5% had free lobes, 21.9% had intermediate lobes and 45.7% had attached or fused.

The proportions of the ear lobe types in the two types of school were not significantly different, though there were slight variations. In the grammar school sample 39.2% had free ear lobes, 19.8% had intermediate ear lobes and 41.0% had attached or fused lobes. The comparable figures for the non-selective school sample were 35.7% free lobes, 21.7% intermediate and 42.5% attached or fused.

There were no significant social class differences. In the male professional group 40.7% had free ear lobes, 14.8% had intermediate lobes and 44.4% had attached lobes. In the middle class males there were rather more with free lobes, 45.6% of the total belonging to this class. Intermediate ear lobes were found in 20.6% of the middle class males and attached lobes in 33.8% of the sample. Free ear lobes were found in 39.6% of the manual class males, 22.6% had intermediate ear lobes and 36.7% had attached ear lobes. The proportions of ear lobe types in the female sample differed from the males because of the basic sex difference in this characteristic. In the females from professional backgrounds 37.5% had free ear lobes, 16.7% had intermediate ear lobes and 45.9% had attached ear lobes. Free ear lobes were found in only 27.6% of the middle class females, 23.0% had intermediate ear lobes and 48.4% had attached lobes. The comparative results for the manual female group were 38.4% with free ear lobes, 21.9% with intermediate ear lobes and 39.8% with attached or fused ear lobes.

In comparison of groups of differing parental origin there appeared to be a lower frequency of persons possessing free ear lobes in the Midland samples, and a lower frequency of attached ear lobes in the English and British samples, though these variations were not significantly different. Free ear lobes were present in 41.6% of the Midland males and 30.2% of the Midland females. In the English sample 46.4% of the males and 34.6% of the females had free ear lobes, and 46.7% of the British males and 37.9% of the females belonged to this class. Attached ear lobes were found in 41.0% of the Midland males and 48.3% of the females. The comparable figures for the English group were 28.6% of the males and 43.7% of the females, and in the British group 33.3% of males and 38.6% of females had attached or fused ear lobes. (tables F7abc)

Ear Lobe Type and Hair Redness

see section 3G.10

3K.2 Ear Lobe Type and Chin Type

A significant association was found between ear lobe type and chin type in the male sample, but not in the females nor in the total sample. There was a significantly higher frequency of males with free ear lobes and without any chin indentation. Of those males with free ear lobes only 30.4% had any chin cleft whereas 37% of those with intermediate lobes also possessed the chin characteristic. In the males with attached or fused ear lobes, 39.5% had a cleft chin. In the females the trend was reversed, there being more cleft chinned persons in the group with free ear lobes, than in the other groups, but these differences were not significant. (tables I 17abc)

3K.3 Ear Lobe Type and Secretor

Because of practical difficulties the comparisons involving the secretor trait used a smaller sample size than the remainder of the comparisons (see Section 2.5). In this comparison a significant association was found between the secretor trait and ear lobe type in the female sample and this association gives rise to a significant result for the total sample. Although there is not significant heterogenity between the male and female samples to disallow the pooling of the data, it is clear that this association did not occur in the males sample. In the female secretors 33.9% had free ear lobes, 15.7% had intermediate ear lobes, 32.3% had attached ear lobes and 18.1% had fused ear lobes. The non-secretor females were found to consist of 28.6% with free ear lobes, 35.7% with intermediate ear lobes, 26.2% with attached ear lobes and 9.5% with fused ear lobes. It can be seen that the points of maximum difference are in the classes intermediate and fused ear lobes.

In general there appears to be a trend towards less attached ear lobes in the non-secretor females. (tables I 18abc)

3L - Chin Type

3L.1 Chin Type Background Results

In the total sample 68.7% had no cleft in their chin, 18.3% had a slight cleft, 5.5% had a deep cleft and 7.5% had a dimpled chin. There were considerable differences between the sexes, though these were not significant. In the males 35.1% had some degree of indentation of the chin but only 28.0% of the females belonged to this group.

There was a significant difference in the chin type frequencies of the two school types. In the total samples only 25.8% of the grammar school pupils had cleft or dimpled chins as compared with 37.9% of non-selective school pupils. On further examination of the data it is found that this association is only significant in the female sample though the same trend can be seen in the male sample. Of the female grammar school pupils only 22.6% had cleft chins whereas 34.2% of the secondary modern girls were so classified. In the male sample 29.7% of the grammar school boys and 40.2% of the secondary modern boys possessed cleft chins. There was no significant heterogenity between the sexes for this trait.

A significant difference was also found in the comparison of different social class groups. This association was present in the total sample and also in the male sub-sample, though not in the females. In the total sample cleft chins were found in 19.6% of the professional group, 30.5% of the middle class group and 42.0% of the manual group. Cleft chins were found in 20.4% of the bpys from professional background, 33.7% of those from middle class background and 54.7% of those with a manual background. Although the differences were not significant the same association could be noted in the female sample. Here cleft chins were found in 18.7% of the professional class, 27.4% of the middle class and 32.9% of the manual group.

There were no significant differences in chin type frequency between groups of different parental origin. In the males only 33.1% of the Midland boys had cleft chins, as did 39.3% of the English and 37.8% of the British. However the Midland girls had the greatest frequency of cleft chins in the female sample. Cleft chins were found in 30.7% of the Midland girls but only 25.4% of the English and 20.7% of the British shared this characteristic. (see F8abc)

Chin Type and Ear Type

See section 3K2

Chin Type and Colour Vision Defect

See section 3E.3

3M - Skin Type

3M.1 Basic Skin-Type Frequencies

The total sample contained 44.5% who had no freckles. Of the remainder 35.5% had light freckling and 20% had heavy freckling. There was no significant sex difference as freckles were found in 54.7% of the males and 56.3% of the females.

The comparison of the two school types showed that the frequencies of the different skin types were very similar in both. In the selective school sample 46.0% had no freckles, 34.9% had light freckling and 19.1% had heavy freckling. Absence of freckles was noted in 42.3% of the secondary modern group and 36.4% had light freckling while the remaining 21.3% were heavily freckled. There was no significant difference between the school types.

There was no significant association of skin type and social class group. The frequencies of subjects with heavy freckling were similar in all three groups. In the professional group 18.8% were placed in this class, as compared with 19.5% of the middle class and 20.6% of the manual group. There was a trend towards an increase in the frequency of freckle absence in the professional class and an increased percentage of lightly freckled individuals in the manual group. Freckles were absent in 41.5% of the professional group as compared with 44.2% of the middle class and 48.4% of the manual group. The lightly freckled class made up 39.7% of the professional but only 36.3% of the middle class and 31.0% of the manual group. However when the data is considered as single sex samples it is found that the proportions of heavily freckled persons in the male sample vary. In the professional males only 16.9% have many freckles, but this characteristic is found in 20.6% of the middle class and 30.1% of the manual group. The largest variation among the females occurs in the group without freckles. This class forms 53.4% of the manual background group, but only 39.5% of the professionals and 41.3% of the middle class group.

A significant association was found for skin type and parental origin. In general this was due to a high frequency of freckled subjects in the British sample and a low frequency in the English sample. Heavy freckling was found in 34.0% of the British sample but only 16.2% of the English and 17.6% of the Midland group showed this characteristic. In the English group only 28.8% showed light freckling as compared with 37.4% of the Midlanders and 36.0% of the British. However 55% of the English had no freckles, the comparable frequencies being 45.0% of the Midland group and 30.0% of the British sample. The male sub sample also showed a significant association of skin type and parental origin, but this association was not significant in the females. The same trend was detectable among the sub-groups of the female sample. (tables F9abc)

<u>Skin Type and Eye Colour</u>

See section 3D.2

<u>Skin Type and Ocular Defect</u>

See section 3F.4

Skin Type and Hair Colour

See section 3G.9

Skin Type and PTC Tasting

See section 3P.3

Skin Type and Weight

See section 3S.9

Skin Type and Height

See section 3S.9

Skin Type and Foot Length

See section 3S.9

3M.2 Skin Type and Stamping Foot Preference

A significant association between skin type and foot preference in stamping was noted in the total sample though not in the single sex samples. In general the absence of freckling was associated with left-footedness and the lack of a definite foot preference. The non-freckled group of the total sample contained 29.5% who were left-footed or mixed footed in stamping, but in those who were freckled either lightly or strongly only 21.8% were not right footed.

The same trend may be detected in the two single sex samples. In the males 76.1% of the non-freckled group were right footed as compared with 83.5% of those with few freckles and 77.6% of those with many freckles. The greater frequency of right footed girls was also found in the group with few freckles. Only 64.3% of the girls with no freckles were right footed, but 75.6% of those with light freckling and 72.1% of those with heavy freckles shared this characteristic. (tables L 7abc)

3N - Mid-digital Hair

3N.1 Basic MDH Frequencies

In the total sample 39.4% had no mid-digital hair. Hair was present on one finger in 19.4% of the population, two fingers in 24.3%, three fingers in 13.6% and all four fingers in 3.2%. Only one subject was found to have a MDH pattern not classified, this case has been included with the group having all fingers with MDH for further discussion. In fact owing to the low frequency of the MDH 4 type (four fingers with MDH) it was necessary to lump together the groups with three or more fingers with hair for statistical purposes.

There was no significant sex difference in MDH types, though the males had a slightly higher percentage of individuals with MDH. In the male group 38.4% had no MDH as compared with 40.2% of the females. The male group contained 28.8% with MDH 1, 27.3% with MDH 2, 12.5% with MDH 3 and only 1.4% with MDH 4. Of the females 18.8% had MDH 1, 22.0% had MDH 2, 14.5% had MDH 3 and 5.0% had MDH 4.

The two school types did not differ significantly in their frequencies of the MDH types, but slight differences were present. In the selective schools only 36.9% had no mid-digital hair as compared with 42.3% of the secondary modern group. However the comparative frequencies for the other MDH types were very similar, MDH 1 was found in 19.1% of the grammar school sample and 19.9% of the non-selective sample. Both groups contained 24.3% with MDH on two fingers. Sixteen percent of the grammar school group had MDH 3 and 5.7% had MDH 4 as compared to 10.7% MDH 3 and 2.9% MDH 4 in the secondary modern sample.

There were no significant differences in MDH type frequency in the different social class groups. It was noted that the professional group had a higher frequency of persons lacking mid-digital hair than the other groups. In the total UK sample 45.1% of the professional group lacked MDH as compared to 37.9% of the middle class and 38.9% of the working-class. This difference appeared to be the result of variation between class groups in the female sample, as the differences in the male sample are slight. In the females 50% of the professional group had no mid-digital hair as compared to 39.1% of the middle class and 35.6% of the manual class. MDH 0 was present in 40.7% of the professional males, 36.3% of the middle class males and 43.4% of the manual males.

30 - Finger Length

30.1 Basic Finger Length Frequencies

In the total sample 39.4% had long index fingers, 20.3% had equal length fingers and 40.4% had long ring fingers. There was a very significant sex difference in this trait. The long index finger type was more common in females. Only 32.2% of the males were so classified as compared to 45.6% of the females. Equal length ring and index fingers were found in approximately equal proportions in the sexes, but the long ring finger type was more frequent in the males. Long ring fingers were found in 49.5% of the males but only in 32.4% of the females.

There were no significant differences between the school types. The long index finger was found in 38.2% of the grammar school sample and 40.8% of the non-selective sample. Equal fingers were noted in 23.1% of the selective group and 16.4% of the secondary modern group, and the comparable figures for the long ring finger type were 38.8% and 42.3%. The single sex samples were also tested for this association but there were no significant differences though there was a trend towards more long ring finger types among the non-selective females. Long ring fingers were found in 36.4% of the secondary modern girls but only 28.8% of the selective school girls.

The social class group comparisons showed no significant differences though there were slight variations in the finger type frequencies. These were most notable in the male sample. The long ring finger type was found in 61.1% of the professional group but only in 45.6% of the middle class and 49.1% of the manual group. The long index finger type was most common in the middle class group where 36.9% possessed this trait. Of the professional males 24.1% had long index fingers and 28.3% of the manual group shared this classification. In the female sample long index fingers were also most frequent in the middle class group, who had 49.7% of this type as compared with 33.8% of the professional and 43.8% of the manual background girls. There was no comparable excess of professional group girls with the long ring finger type, but the equal finger type was found to be most frequent in this class. Among the professional females 35.4% had equal fingers as compared to 20.7% of the middle class and 19.2% of the manual group.

When the three geographical groups were compared there were no significant differences, though the proportions of the different hand type varied slightly. The greatest frequency of long index finger types was found in the Midland group. This trait was found in 34.8% of Midland males and 49.3% of the females, but only 26.8% of English males and 38.2% of the English females had this characteristic. In the British group 28.9% of the males and 39.7% of the females had long index fingers. In both sexes the highest frequency of persons with equal length fingers was found in the English group. Twenty-five percent of the males and 28.5% of the females had equal length fingers. The comparable fingers for the Midland group were 15.7% of the males and 21.0% of the females, and in the British sample 20.0% of males and 22.4% of females shared this trait. Approximately equal percentages of long ring fingers were found in the three sub-groups of the main sample. In the females the Midland group had a lower frequency of long ring fingers than the English or British samples. Only 29.8% of the Midland girls were put into this class as compared to 35.4% of the English and 37.9% of the British. (tables F11abc)

Finger Length and Ocular Defect

See section 3F.5

30.2 Finger Length and Writing Laterality

A significant association was found between finger type and the hand used for writing in both the total sample and the male sample. A higher frequency of left handed persons was found among those whose ring finger exceeded their index finger in length. In the total sample 15.7% of those with a long ring finger were left handed as compared to only 7.5% of those whose fingers were equal and 7.7% of those with a long index finger. Both the long index finger group and the equal finger groups contained 7.8% of left handed writers, but in the long ring finger group 18.1% wrote left handed. Though this association was not present in the female sample the same trend can be detected. Left handed writers formed 12.7% of the long ring finger group but only 7.3% of the equal type and 7.6% of the long index finger group. (see table L2abc)

30.3 Finger Type and Unscrewing a Jartop

A significant association between finger type and the hand used to unscrew a jartop was present in the total sample. This association was not found in the single sex samples, though the trend in both was the same. In all the samples there was a higher frequency of left hand users in the long ring finger class. In the total sample 28.6% of the long ring finger group used their left hand for this activity as compared with 20.8% of the equal finger group and only 18.7% of those with long index fingers. In the males left handed jar openers formed 31.2% of the long ring finger group, 27.5% of the equal group and 24.4% of the long index finger type. The long ring finger group of females contained 25.2% who opened a jar with their left hand, but only 15.9% of the equal finger group and 15.2% of the long index group shared this classification. (table L3abc)

Finger Length and Weight

See section 3S.14

3P - PTC Tasting

3P.1 Form of Results

As previously explained (see Methods 2R.7) the PTC tasting results may either be treated as a distribution with 14 classes, or the distribution may be divided at the antimode to give two classes taster and non-taster. In general calculations have used the natural antimode between solutions 3 and 4, but earlier calculations used the division between solutions 6 and 7, as this was the antimode expected from the literature. In general the chisquare test was used in the two class comparisons, and the Kolmogorov-Smirnov test was used to investigate the whole 14 class distributions.

3P.2 PTC Tasting and Background Variables

There was no significant association of PTC tasting and sex either in the distribution as a whole or in the taster/non-taster classes. In the total sample 20.0% were non-tasters on the 3/4 division, and 29.9% were non-tasters if the distribution was divided between solutions 6 and 7. The figures for the single sex samples were very similar. The 3/4 division non-tasters formed 20.2% of the male sample and 19.9% of the female sample, while the 6/7 division non-tasters made up 29.9% of the male group and 30.0% of the females.

In the school type comparison there was no significant association of PTC tasting and school type in either the total sample or the single sex samples. There was however a slightly larger percentage of 6/7 non-tasters in the non-selective groups of both sex. In the selective groups, 28.4% of the males and 28.8% of the females were 6/7 non-tasters. The comparable results from the non-selective sample were 31.5% for the males and 31.4% for the females. However when the distribution is divided between solutions 3 and 4 the same trend is present in the females, but it is reversed in the males. In the selective school males 21.7% were 3/4 non-tasters as compared with 18.5% of the non-selective males. Of the selective females only 19.2% were 3/4 non-tasters in comparison with 20.7% of the secondary modern girls.

No association of PTC tasting and social class could be demonstrated by means of chisquare tests but comparison of the whole PTC distribution by Kolmogorov-Smirnov tests gave significant results in both sexes. In the males the PTC taste threshold distributions of the professional and the manual groups were found to differ significantly. Inspection of the data showed a deficit of 3/4 non-tasters in both the professional and manual males, while the professional group also showed a deficit of 6/7 non-tasters. In fact the distribution of the manual group's taste thresholds could be interpreted as trimodal with peaks in the taster range at 7 and 9. Only 13.5% of the manual group and 15.0% of the professional group were 3/4 non-tasters as compared with 24.4% of the middle class group. The second category of non-tasters formed 20.7% of the professional males, 32.6% of the middle class and 30.7% of the manual group. In the female sample it was found that the distribution of taste thresholds in the middle class group was significantly different from that of the manual group. There was also a significant difference between the manual group and the combined middle and professional classes. From the data it was noted that there was a deficit of 3/4 non-tasters in the middle class girls, and an excess of 6/7 non-tasters in the manual group. Only 17.9% of the middle class girls were 3/4 non-tasters, as compared with 22.9% of the professional group and 23.3% of the manual group. When the distributions were divided between solutions 6 and 7, 26.3% of the middle class group were non-tasters in comparison with 31.3% of the professional group and 37.0% of the manual group.

Parental origins were not significantly associated with PTC tasting in any group. Among the males there were 20.3% non-tasters in the Midland group as compared with 21.4% in the English and only 17.8% in the British boys. Similarly 6/7 non-tasters made up 29.9% of the Midland male group, 32.1% of the English group and 26.7% of the British group. In the female sample the pattern was different. Only 18.0% of the Midland females were 3/4 non-tasters in comparison with 23.6% of the English and 22.8% of the British. There was a notable excess of 6/7 non-tasters in the British females. In this group 35.1% were non-tasters in comparison with 28.3% of the Midland group and 30.9% of the English group. (tables F12abc)

3P.3 PTC Tasting and Skin Type

A significant association between PTC tasting and freckling was noted in the male sample, but not in the female group of the total sample. No significant associations could be demonstrated in any group using the Kolmogorov-Smirnov test, but chisquare tests showed significant results in the males when the 3/4 taster/non-taster division was used. From the results it would appear that in males the proportion of non-tasters of PTC decreases with increased freckling. In the non-freckled group 27.1% were 3/4 non-tasters, but in the lightly freckled group only 15.6% were so classified and only 12.9% of the heavily freckled boys were non-tasters. Similarly the 6/7 division gave 36.7% non-tasters in the non-freckled group, 30.0% in the lightly freckled and 19.3% in the heavily freckled boys. The same trend could not be detected in the girls. The percentages of 3/4 non-tasters were moderately similar in all three groups, with a slight excess in the heavily freckled females. The non-freckled female group contained 18.8% non-tasters while the lightly freckled had 19.9% and the heavily freckled had 22.3%. In the 6/7 division the differences were more marked, with a large excess of non-tasters in the heavily freckled group. Only 28.9% of the non-freckled group and 28.2% of the lightly freckled group were non-tasters in comparison with 36.0% of the heavily freckled group. This is a reversal of the situation in the male sample. (tables I 20abc)

3P.4 PTC Tasting and Mid-digital Hair

When the PTC taste threshold distributions of the different MDH types were compared using the Kolmogorov-Smirnov test, there were no significant differences in the female sample, but in the males MDH 2 subjects were found to differ significantly from MDH 0, MDH 1 and MDH 3+4. In chisquare tests using the 3/4 division there were no significant results, but when the 6/7 division was used it was found that both the male and the female samples showed significant differences. However the total sample showed no significant association of PTC and MDH, because a large degree of heterogenity was present. Neither sex showed a clear pattern of association of PTC tasting and MDH type. In the males there was a deficit of non-tasters in the MDH 2 group, while the MDH 3+4 group contained an excess of non-tasters. But among the females there was a deficit of non-tasters in the MDH 3+4 group. The 3/4 non-tasters formed 19.8% of the MDH 0 group males, 20.6% of the MDH 1 group, 13.3% of MDH 2 and 33.3% of MDH 3+4. Similarly when the distribution was divided at 6/7 the results were 33.0% for MDH 0, 30.9% for MDH 1, 16.0% for MDH 2 and 46.2% for MDH 3+4. Among the females 3/4 non-tasters made up 18.8% of the MDH 0 group as compared with 24.6% of the MDH 1 group, 25.7% of the

MDH 2 group, and only 11.2% of MDH 3+4 girls. The 6/7 non-taster class made up of 28.1% of the MDH 0 female group in comparison with 33.4% of the MDH 1 group, 37.1% of the MDH 2 group and only 17.7% of the MDH 3+4 group. (see tables I 19abc)

3P.5 PTC Tasting and Chroma

PTC tasting and chroma were found to be significantly associated in the female sample, but not in the males nor in the total sample. In fact the association in females is only significant when the PTC data is divided between solutions 6 and 7; calculations involving the 3/4 division do not give significant results. From the data it would seem that there is a greater tendency for the PTC non-tasters to have hair with a greater intensity of colour (higher chroma number). In the female non-tasters 37.8% had chroma 1 or 2, 31.1% had chroma 3, 21.2% had chroma 4 and 10.0% had chroma of 5 or more. The comparable figures for the female tasters were 36.7% chroma 1 or 2, 44.8% chroma 3, 14.8% chroma 4 and 3.8% chroma 5+. The male sample failed to show the same trend. Among the male non-tasters 58.6% had chroma 1 or 2, 30.6% had chroma 3, 8.0% had chroma 4 and 2.7% had chroma readings of 5 or more. The taster male group contained 53.1% chroma 1 or 2, 33.8% chroma 3, 9.2% chroma 4 and 4.0% chroma 5+. (tables I 13abc)

3P.6 PTC Tasting and Card Dealing Preference

When the data was examined by chisquare test, using the 3/4 division, it was found that PTC tasting and card dealing preference were significantly associated in the total sample and in both single sex samples. The Kolmogorov-Smirnov tests showed no significant difference between the laterality classes in the males or in the total sample, but there was a significant difference in the females. In the males 30.3% of the left-handed group were 3/4 non-tasters, and 42.3% were 6/7 non-tasters, in comparison with 17.2% and 26.2% in the right handed group. Similarly among the females 36.9% of the left-handed group were 3/4 non-tasters and 47.7% were 6/7 non-tasters, while the right handed female group contained only 17.2% 3/4 non-tasters and 27.3% 6/7 non-tasters. In the total sample the comparable figures were 33.0% 3/4 non-tasters and 44.6% 6/7 non-tasters among the left handed subjects. The total right handed group contained only 17.2% 3/4 non-tasters and 26.8% 6/7 non-tasters. (see tables L5abc)

3P.7 PTC Tasting and Needle Threading

A significant association between PTC tasting and needle threading preference was noted in the female and total samples, though not among the males. None of the Kolmogorov-Smirnov comparisons gave a significant result, but chisquare tests using the 3/4 division were significant as previously noted, and a 2 x 13 chisquare contingency table using the total sample also gave a significant result. Though the results for the male sample were not significant, the same trend as the female sample could be detected in this group. In the females the left handed group contained 30.7% 3/4 non-tasters and 38.4% 6/7 non-tasters, while the right handed group included only 17.1% 3/4 non-tasters and 27.9% 6/7 non-tasters. Among the males the difference was less marked. The first non-taster division made up 23.8% of the left handed male group, while the 6/7 non-tasters formed 32.8% of the group. The right handed male group contained only 18.9% 3/4 non-tasters and 28.2% 6/7 non-tasters. In the total sample the two non-taster groups made up 27.2% and 35.6% of the left handed group, while in the right handed group only 17.9% were 3/4 non-tasters and 28.0% were 6/7 non-tasters. (table L4abc)

3Q - Secretor Trait

3Q.1 Basic Frequencies for Background Variables

It was found that 53.1% of the total sample were unable to provide an adequate sample of saliva. Of the remainder 36.0% were secretors and 10.9% were non-secretors. If the percentages are recalculated to include only those who provided a saliva sample, a total of 280, it is found that 76.4% are secretors and 23.6% non-secretors.

There was no significant difference between the sexes, though there were rather more non-secretors among the females. In the males, 20.7% were non-secretors, as compared with 24.9% of the females.

There was no significant difference in frequency of secretors between the two school types. In the grammar school sample 22.0% were non-secretors and 24.8% of the non-selective school group were placed in this category.

The social class group comparison showed that the secretor trait was not significantly associated with this background variable. In the male sample 25.0% of the professional group were non-secretors as compared with 20.3% of the middle class group and 20.0% of the manual group. The female sub-sample showed a slight deficit of non-secretors in the middle class group. Only 20.0% of these girls were non-secretors but 27.4% of the professional group and 28.6% of the manual group shared this classification.

In the comparison of groups of different parental background there were no significant differences, though there were variations between classes. These variations were most marked in the female sample, where only 16% of the British sample were non-tasters in comparison to 29.2% of the Midland girls and 25.8% of the English girls. In the male sample these differences were not noted and the proportion of non-tasters was similar in all three groups. The Midland male group contained 21.5% non-secretors, the English males had 19.2% non-tasters and 20.0% of the British group fell into this group. (tables F13abc)

Secretor Trait and Ponderal Index

See section 3S.12

Secretor Trait and Ear Type

See section 3K.3

3R - Laterality

3R.1 Basic Frequencies and Sex Differences in Laterality

Owing to the close association between the majority of the laterality variables it has been decided to report all the laterality results in a single section. Where the number of persons ambilateral with regard to a particular trait is small, these persons are included in the left sided group for the purposes of discussion. In five of the ten laterality variables there was a statistically significant excess of left biased males, while in the remaining five there was a slight excess of left sided males.

In the total sample 10.9% were left handed for writing. However when the single sex samples are compared it is found that 12.9% of the males were left handed in comparison with only 9.1% of the females. These differences were not statistically significant.

Laterality in dealing cards was found to be significantly associated with sex. Left hand users formed 19.0% of the total sample, but in the male group 23.9% were left handed. Only 14.7% of the females dealt cards with their left hands.

There was only a small difference between the sexes in eye dominance, and this was not statistically significant. The total group contained 30.1% with a dominant left eye. In the males the comparable figure was 31.5% while the female group included 28.9% left-eyed.

Laterality preference in throwing a ball showed little sex difference when the ambidextrous persons were included with the left-handed. In the total sample 13.6% were either left or ambidextrous, while 14.4% of the males and 13.0% of the females belonged to this class. When the left handed throwers are separated from the ambidextrous it is noted that 13.3% of the males were left handed in comparison with 6.7% of the females.

Laterality in use of a racquet such as a tennis racquet was found to show a significant sex difference. In the male sample 15.5% were left handed in racquet use, while only 8.8% of the females showed this characteristic. The total sample contained 11.7% left handed racquet users.

In use of a hammer the sex difference was less notable and not significant. Left handed hammer users formed 12.5% of the total sample. In the male sample 15.5% were left handed for this activity in comparison with 9.8% of the females.

Threading a needle was an activity that did not show any significant association with sex, though again there was a greater proportion of left handed males. The total sample included 22.3% who were left handed in threading a needle. The comparable figure for the male sample was 24.4% while only 20.5% of the females used their left hand.

There was a notable sex difference in the hand use for unscrewing a jartop. This difference was statistically significant.

In the total sample 23.2% of persons used their left hand to take off the jartop. Among the males 28.3% were left handed. but only 18.6% of the females showed this characteristic, a difference of 9.7%.

In both the foot activities there were large percentages of ambilateral persons, and so the three laterality classes will be reported separately. There was a significant association of stamping laterality with sex. Among the males 16.5% were left footed and 14.0% were ambilateral, while in the female sample 11.7% were left footed and only 9.1% anbilateral. The total sample contained 13.9% left footed and 11.4% ambilateral.

Laterality in kicking a ball was also found to show a significant sex difference. In the male sample 12.2% were left footed and 18.7% ambilateral, in comparison with 8.8% left and 10.4% ambilateral in the females. The total sample contained 10.4% left footed and 14.3% who were ambilateral in kicking a ball. (tables G1 - G10ab)

3R.2 School Type and Laterality

There were no significant associations between school type and laterality in the total sample, but when the single sex samples were examined it was found that the two sexes showed opposing trends. In males there was a tendency to an excess of left side dominance in the non-selective schools. Significant differences between the school types were found in the male sample for laterality in writing and in dealing cards. In the females the results were not significant, but there was in most activities a trend towards an increased percentage of left dominant persons in the selective samples.

As stated above writing handedness was significantly associated with school type in males. Only 8.1% of the selective school boys were left handed in comparison with 18.3% of the non-selective group. However in the females 9.1% of the selective females were left handed, but only 7.8% of the secondary modern girls showed this characteristic. In the total group 8.6% of the grammar school children were left handed but only 13.6% of the non selective group.

Laterality preference in dealing cards also showed a significant association with school type in the male sample. The grammar school males included 18.4% left handed for this activity in comparison with 30.2% of the non selective group. However among the girls 16.5% of the selective group were left handed but only 12.2% of the non-selective group. In the total sample left handed persons formed 17.4% of the grammar school group and 20.8% of the secondary modern group.

Eye dominance was the only laterality variable other than needle threading to show a higher percentage of left dominance in the grammar school group of males. There was no significant association with school type in any group. In the total sample 32.0% of the selective school group and 27.9% of the non selective group had left eye dominance. Among the males 33.1% of the grammar school group were left eyed in comparison with 29.8% of the non-selective group;

while 31.1% of the selective school females and 26.2% of the non selective females showed left eye dominance.

Laterality preference in throwing a ball showed the same trends as the traits preceding eye dominance above. In the male grammar school group 12.8% were left handed in throwing a ball while 16.0% of the secondary modern boys showed this trait. Among the females 14.3% of the grammar school group were left handed in comparison with 11.4% of the non selective girls. These figures combine to give no difference between school types in the total sample with regard to the percentage of left hand users. Both school types contained 13.6% left handed ball throwers.

In use of a racquet 12.3% of the grammar school boys were left handed as compared with 18.3% of the secondary modern boys. The female selective sample contained only 8.0% left handed, while 10% of the secondary modern girls showed this characteristic. In the total sample 9.9% of the grammar school children were left handed in using a racquet as compared with 13.9% of the secondary modern group.

In the laterality preference for use of a hammer there was a notable difference between the school types in the male sample, but this difference was not significant. Only 12.2% of the grammar school boys were left handed in comparison with 19.1% of the non selective boys. In the female sample the differences were not marked. The grammar school sample contained 10.2% left handed while 9.4% of the non selective group were put in this class. The total grammar school sample contained 10.2% left handed in comparison with 14.1% of the non selective group.

The differences between the school type in laterality preference for threading a needle were slight. In the total sample 22.4% of the grammar school sample and 22.3% of the non-selective sample were left handed. Among the males 25.4% of the grammar school sample were left handed in comparison with 23.3% of the non selective males. The female grammar school group contained 19.9% left handed while the non selective female group included 21.2% who used their left hand for this activity.

The same trend was shown in both the single sex samples in the laterality preference for unscrewing a jartop, and the differences between the school types were comparatively small. In the total sample 21.6% of the grammar school group and 25.0% of the non-selective group were left handed. The selective male sample included 27.0% left handed in comparison with 29.0% of the non-selective group. Left handed girls made up only 17.0% of the female grammar school group in comparison with 20.6% of the non-selective group.

In preference in foot stamping the total grammar school sample contained 12.7% left footed and 10.2% ambilateral, while the comparative figures for non selective schools were 15.4% left and 12.9% ambilateral. The male sample showed the usual excess of left dominance in the non selective group. In the grammar school males 12.2% were left footed and 12.9% ambilateral, but in the secondary modern group 21.4% were left footed and 15.3% ambilateral. There were less notable differences in the female sample. Here 13.1% of the selective school girls were left footed, and 8.0% ambilateral, in comparison with 9.9% left and 10.6% ambilateral in the non selective group.

Laterality preferences in kicking a ball did not differ significantly between the school types. In the total sample the grammar school group included 10.5% left footed and 13.6% ambilateral, while the non selective group contained 10.3% left footed and 15.1% ambilateral. Among the males the grammar school sample contained only 9.5% left footed and 17.0% ambilateral as compared with 15.3% left and 20.0% ambilateral in the secondary modern group. The female grammar school group contained 11.4% left footed girls and 10.8% ambilateral, but only 5.7% of the non-selective school girls were left footed and 9.9% of this group were ambilateral. (tables G1a(iv) b(iv) c(iv) to G10 a(iv) b(iv) c(iv))

3R.3 Laterality and Class Group

There were no significant associations between social class groups and laterality in any of the samples. In writing preference left handedness was found in 11.8% of the total professional sample, 11.0% of the middle class and 10.3% of the manual group. The professional male group contained 14.8% left handed boys, while 13.1% of the middle class and 10.8% of the manual group were left handed. Among the females 8.4% of the professional group were left handed in comparison with 9.0% of the middle class and 9.9% of the manual girls.

In dealing cards there was a deficit of left handed persons in the manual group. The total sample professional group contained 19.6% left handed, while 20.9% of the middle class group were also left handed in comparison with only 14.4% of the manual. In the male sample 25.9% of the professional group and 25.8% of the middle class group were left handed, but only 17.7% of the manual group had this classification. Left handed girls made up 12.5% of the professional group, 16.5% pf the middle class group and 12.1% of the manual group.

In the case of eye dominance it was found that in the total sample 32.1% of the professional group, 29.2% of the middle class group and 30.7% of the manual group had a dominant left eye. In the males a dominant left eye was present in 33.3% of the professional group, 31.9% of the middle class and 29.2% of the manual group. Girls with dominant left eyes formed 31.3% of the female professional group as compared with 26.8% of the middle class and 31.9% of the manual group.

The total sample professional group contained 16.7% who were left handed in throwing a ball while the middle class group had only 13.4% and the manual group had 12.2% in this class. Left handed boys made up 16.7% of the professional group in comparison with 14.4% of the middle class and 12.3% of the manual group. The female sample also contained 16.7% left handed persons in the professional group, with 12.2% in the middle class and 12.1% in the manual group.

In the comparison of laterality preference in using a racquet by social class group it was found that there was a slight excess of left handed persons in the total professional group. In this group 16.6% were left handed in comparison with only 11.9% in the middle class and 8.4% in the manual group. Similarly in the male sample 24.1% of the professional group were left handed in comparison with 13.2% of the middle class and 12.3% of the manual group. In the females the greatest proportion of left handed girls was found in the middle class group. Only 8.4% of the professional group and 5.5% of the manual group were left handed in comparison with 10.7% of the middle class.

The pattern of results for the laterality preference in using a hammer is similar to that for use of a racquet. In the total sample 13.7% of the professional group were left handed in comparison with 13.1% of the middle class group and 10.3% of the manual group. However in the male sample 18.6% of the professional group were left handed while only 15.7% of the middle class and 12.3% of the manual group showed this characteristic. The comparable figures for the female sample were 8.3% for the professional group, 10.8% for the middle class group and 8.8% for the manual group.

The activity of threading a needle was performed left handed by a comparatively large proportion of the population studied. In the total sample it was found that 29.7% of the professional group were left handed in this activity in comparison with 21.5% of the middle class and 19.4% of the manual group. Among the males the professional group contained 34.0% left handed persons while the middle class had onlt 22.9% and the manual group had 20.3% in this class.

Left handed girls made up 25.1% of the professional females, but only 20.2% of the middle class females and 18.7% of the manual females showed this trait.

In unscrewing a jartop it was noted that 25.5% of the total professional sample used their left hands, while 23.6% of the middle class and 20.5% of the manual group were also left handed. Among the males the professional group contained 35.2% left handed as compared with 29.4% in the middle class and only 20.0% in the manual group. The female sample included 14.6% left handed in the professional group, 18.5% in the middle class and 20.9% in the manual group.

The laterality preference for stamping out a spark showed an increased percentage of left footedness in the total professional sample. In this group 18.6% were left footed as compared with 13.3% in the middle class group and 12.3% of the manual group. Ambilateral stamping was found in 11.8% of the professional group, 11.2% of the middle class group and 11.6% of the manual group. The results for the male sample showed a similar pattern. In the professional male group 24.1% were left footed and 9.3% ambilateral, while in the middle class the comparable results were 13.8% left footed and 15.6% ambilateral, and the mannual male group contained 17.1% left and 14.1% ambilateral. In the female sample the professional group included 12.8% with left foot dominance and 14.6% ambilateral. The middle class female group contained 12.9% left foot users and 7.3% ambilateral, while the comparable results for the manual girls were 8.8% left footed and 9.9% ambilateral.

As with stamping out a spark, the laterality activity of kicking a ball was found to be carried out without lateral dominance in substantial proportions of the subjects. In the total sample left footed kickers formed 14.7% of the professional group, 10.1% of the middle class group and 8.4% of the manual group. Ambilateral kickers formed 14.7% of the professional group, 16.0% of the middle class group and 10.3% of the manual group. Among the males the professional group contained 16.7% left footed and 18.5% ambilateral, while the comparable figures in the middle class males were 10.0% left and 21.3% ambilateral, and in the manual group 14.1% were left footed and 12.5% were ambilateral. The female professional sample included 12.5% left footed and 10.4% ambilateral members, in comparison with 10.1% left and 11.2% ambilateral in the middle class, and 4.0% left and 8.8% ambilateral in the manual group. (tables G1a(ii) b(ii) c(ii) - G10a(ii) b(ii) c(ii))

3R.4 Laterality and Parental Origins

There were no significant associations between laterality variables and parental origin in either the total sample or the two single sex samples. In the total sample 10.7% of the Midland group were left handed, in comparison with 9.0% of the English and 12.7% of the British group. Among the males there was an excess of left handed writers in the British group. Here 17.8% were left handed, as compared with only 11.8% of the Midlands males and 12.5% of the English males. In the female sample the trend was reversed with 10.3% left handed in the Midland group, 5.5% in the English and 8.6%

in the British girls.

In dealing cards it was found that the variation in proportions of left handed persons by parental origin was only slight. The total sample professional group contained 19.7% left handed as compared with 18.9% in the English group and 16.8% in the British group. Among the males left handed persons formed 22.0% of the Midland group, 21.4% of the English group and 23.3% of the British. The comparable results for the female sample were 14.9% left handed in the Midland group, 16.3% in the English group and 12.0% of the British group.

From the results there appears to be a deficit of persons with a dominant left eye among the English group. Only 21.6% of the total English group were left eyed as compared with 32.6% of the Midland group and 30.1% of the British group. Similarly in the male sample 23.2% of the English group showed left eye dominance while 33.7% of the Midlanders and 33.3% of the British shared this characteristic. Among the females the English group contained 20.0% with left eye dominance, but the Midland girls included 31.7% with this trait, and 27.6% of the British group were also left eyed.

In the total sample there was little variation in the percentage of the parental origin group who were left handed in throwing a ball. The total Midland group contained 13.3% left handed while 13.5% of the English and 14.6% of the British showed this trait. Among the males there was more variation. Only 13.0% of the Midland males and 14.3% of the English were left handed in comparison with

20.0% of the British boys. In the female sample 13.7% of the Midland group were left handed in comparison with 12.7%of the English group and 10.3% of the British girls.

Laterality preference in the use of a racquet was not significantly associated with parental origins, though there was a slight trend to an increased proportion of left handed persons in the British group. In the total sample the Midland group contained 11.5% left handed while 9.9% of the English and 14.7% of the British were also left handed for this trait. The Midland male group contained 15.2% left handed boys, while the English group included 12.5% and in the British 18.2% of the boys used a racquet with their left hand. In the female sample 8.3% of the Midland girls, 7.2% of the English girls and 12.1% of the British were left handed.

In using a hammer it was found that 12.9% of the total Midland group preferred their left hand. The English sample included 11.7% left handed and 11.7% of the British sample also belonged to this class. Among the males 14.7% of the Midland group were left handed, in comparison with 16.1% of the English and 17.8% of the British. The female sample contained a lower overall percentage of left handed users but there appeared to be an increased proportion of this type in the Midland group. In the Midland females 11.4% were left handed, while 7.3% of the English and 6.9% of the British were also left handed.

There were no significant differences in laterality preferences for threading a needle in the parental original groups.

In the total sample the Midland group contained 21.6% who used their left hand, while 27.3% of the English and 19.6% of the British also showed this characteristic. Among the males there was an excess of left handed boys in the English group. In this group 30.9% used their left hand in this activity in comparison with 21.7% of the Midland group and 27.2% of the British. In the female sample 21.6% of the Midland girls and 23.6% of the English were left handed, in comparison with only 13.8% of the British.

The results for preferred hand in unscrewing a jartop show an excess of left handed persons in the British males and total sample, while in the female sample there is a slight excess of left handed girls in the Midland group. In the total sample only 21.7% of the Midland group and 24.3% of the English group were left handed for this activity, in comparison with 27.2% of the British group. The difference in the male sample was more extreme. Here 25.9% of the British boys were left handed in threading a needle, but only 17.2% of the Midlanders and 16.4% of the English showed this trait. In the female sample 32.1% of the English girls were left handed in comparison with 27.0% of the Midland group and 28.9% of the British.

The relative proportions left footed or ambilateral in stamping out a spark were similar in all three parental origin areas. In the total sample 14.4% of the Midland group were left footed and 12.1% were ambilateral. The total English group contained 14.4% left footed and 9.0% ambilateral, while in the British group there were 11.7% of left footed persons and also 11.7% ambilateral persons. In the males sample the Midland group contained 18.1% who used their left foot in stamping out a spark, while 14.7% would use either foot. Similarly in the English males 14.3% were left footed and 8.9% were ambilateral, and in the British males 13.3% were left footed while 17.8% were ambilateral. The results for the female sample show that a dominant left foot was present in 11.3% of the Midland girls, 14.5% of the English sample and 10.3% of the British. Those who were ambilateral for stamping made up 9.8% of the Midland female sample, 9.1% of the English girls and 6.9% of the British group.

Foot preference in kicking a ball was not associated with differences in parental origin. In the total sample left footed kickers formed 10.5% of the Midland group, 11.7% of the English group and 8.7% of the British, while the comparable percentages for ambilateral kickers were 14.4%, 16.2% and 11.7%. Among the males the Midland group contained 10.7% left footed and 19.8% ambilateral. The English males included 16.1% who were left footed and 21.4% ambilateral, while 13.3% of the British were left footed and 11.1% ambilateral. The Midland female group included 9.7% left footed kickers, while 19.8% were ambilateral. In the English female group 16.1% were left footed and 21.4% were ambilateral, while the comparable figures for the British girls were 13.3% left and 11.1% ambilateral. (tables G1a(iii) b(iii) c(iii) - G10a(iii) b(iii) c(iii))

3R.5 Interactions between Laterality Variables

With a total of ten laterality variables there are 45 different possible associations between pairs of laterality variables. Each of these 45 associations can be considered with regard to the total sample and each of the single sex samples. Two by two chisquare contingency tests were used to investigate possible associations. In each comparison the results of the Chisquare tests were examined in order to check that there was no significant heterogeneity between the male and female subsamples. In reporting the results of these tests 'left' is used to include the small number of persons undecided in laterality choice as well as true left sided persons.

As might have been anticipated, there was a high degree of association between the majority of the laterality variables. In the total sample only one possible association failed to reach significance: kick by dominant eye. In fact 41 of the 45 associations showed as significant at the 0.1% level. Of the remaining associations dominant eye by stamp was significant at the 1% level, while dominant eye by unscrew jartop and dominant eye by thread needle were only significant at the 5% level.

In the males all the comparisons were significant except dominant eye by thread needle. Of the remaining 44 associations dominant eye by kick was only significant at the 5% level, but dominant eye by deal cards, use racquet, unscrew jartop and stamp were significant at the 1% level, as were also stamp by thread needle and kick by unscrew jartop.

Among the females there were six possible associations that lacked significance. These were all comparisons involving dominant eye, and a further two comparisons with dominant eye were only significant at the 5% level as compared with 0.1% for the remainder of the comparisons. The non-significant associations were dominant eye by deal, throw ball, thread needle, unscrew jartop, stamp and kick, while dominant eye by hammer and use racquet were only significant at the 5% level. (table J1abc)

3R.6 Writing Preference and Kicking a Ball

This association was very highly significant in all three groups. In the total sample 72.3% of the left handed writers were left kickers, while only 18.9% of the right writers were left kickers. Similarly in the males 72.2% of the left writers and 24.8% of the right writers were left kickers, and in the females 72.4% of the left writers and 13.9% of the right handed writers were left footed kickers. (table J2abc)

3R.7 Writing Preference and Stamping Out Spark

These variables were very highly significantly associated in all three sample. The left handed writer group in the total sample contained 75.4% left footed stampers, but only 19.2% of the right handed writers were left footed. In the males 80.6% of the left writers were left stampers while 30.1% of the right handed writers were left footed. The female left handed writer group contained 69.0% left footed, and the right handed group contained only 16.0% left footed. (table J3abc)

3R.8 Writing Preference and Unscrewing a Jartop

Again all three groups showed a very highly significant association between these two variables. In the total sample 73.8% of the left writing group were left handed in unscrewing a jartop in comparison with 16.9% of the right writing group. Among the males the comparable figures were 80.6% for left writing boys left handed in unscrewing a jartop and 20.6% for right handed writers left handed in jartop unscrewing. The left handed writing female group contained 65.5% left jartop unscrewers while the right writing females had only 13.9% left jartop unscrewers. (table J4abc)

3R.9 Writing Preference and Threading a Needle

This association was very highly significant in all three samples. The left handed writers in the total sample included 81.3% who were also left handed in threading a needle, but only 14.9% of those who were right handed in writing used their left hand to thread a needle. Similarly in the male sample 82.9% of the left handed writers were left handed for threading a needle while 15.9% of the right handed writers used their left hand for this activity. Of those females who used their left hand in writing 79.3% used their left hand in threading a needle, but only 14.6% of the right handed girls threaded a needle with their left hand. (table J5abc)

3R.10 Writing Preference and The Use of a Hammer

All three samples showed a very highly significant association of these two laterality traits. In the total sample the left handed writers included 81.5% who also used a hammer with their left hand, while only 4.0% of the right handed writers used the left hand for hammering. Among the males 94.4% of the left handed writers were also left handed in use of a hammer, the comparable figure for right handed writers being only 3.7%. In the left handed female writers 65.5% were also left handed in hammer use, while only 4.2% of the right handed writers showed this characteristic. (table J6abc)

3R.11 Writing Preference and the Use of a Racquet

These two traits were very highly significantly associated in all three samples. In the total sample 76.9% of the left handed writers were left handed for use of a racquet as compared with only 3.8% of the right handed writers. The left handed writing male group included 83.5% who were left handed for using a racquet, while 5.0% of the right handed writers were left handed for this activity. In the female sample 69.0% of the left handed writers were also left handed in use of a racquet, in comparison with only 2.9% of the right handed writers of the female group. (table J7abc)

3R.12 Writing Preference and Throwing a Ball

As with all the other associations with writing preference, the association of writing and throwing a ball was a very highly significant in all three samples. The left handed writers of the total sample included 78.3% who also used their left hand in throwing a ball, while only 5.6% of the right handed writers were left handed in throwing. Among the males 83.3% of the left handed writers were left handed in throwing a ball but only 4.1% of the right handed writers fell into this category. In the female sample 72.4% of the left handed writers used their left hand in throwing, as compared with 6.9% of the right handed writers. (table J8abc)

3R.13 Writing Preference and Eye Dominance

Writing preference and eye dominance were very highly significantly associated in the total sample and the single sex samples. In the total sample 61.5% of those who used their left hand in writing had a dominant left eye, whereas 26.2% of the right handed writers were left eyed. Among the males the left handed writer group contained 61.1% with left eye dominance while the right handed writer group included 27.2% with a dominant left eye. Similarly in the females 62.0% of the left handed writers possessed a dominant left eye, in comparison with 25.3% of those who used their right hand in writing. (table J9abc)

3R.14 Writing Preference and Dealing Cards

These two variables were associated at a very high level of significance in all three samples. In the total sample 90.8% of the left handed writers used their left hand in dealing cards, but only 10.1% of the right handed writers showed this characteristic. Among the males all the left handed writers were also left handed in dealing cards and only 12.5% of the right handed writers were left handed for this activity. The female sample of left handed writers included 79.3% who were left handed in dealing cards while 8.8% of the right handed writers were left handed in dealing cards. (table J10abc)

3R.15 Dealing Cards and Kicking a Ball

It was found that laterality preference in dealing cards was associated with laterality preference in kicking at a very high level of significance, in the total sample and in the single sex samples. The left handed group in the total sample contained 58.0% who were also left footed in kicking, while in the right handed group 17.2% were left footed. In the male sample 60.6% of the left handed males were left footed in kicking a ball as compared with 21.9% in the right handed males. Among the females 54.4% of the left handed girls used their left foot in kicking, while 13.4% of the right handed girls were left footed. (tableJ11abc)

3R.16 Dealing Cards and Stamping

In each of the samples laterality preference in dealing cards was associated with laterality in stamping at a very highly significant level. The total sample left handed group contained 60.7% who were also left footed, while the right handed group contained only 17.4% in this class. Among the males 60.6% of the left handed group were also left footed, but only 21.4% of those using their right hand in dealing used their left foot in kicking. The female sample included 60.9% left footed girls in the left handed group and 14.2%left footed in the right handed group. (table J12abc)

3R.17 Dealing Cards and Unscrewing a Jartop

These two laterality activities were found to be very highly significantly associated in both the total sample and the two single sex samples. In the total sample 71.4% of the left handed card dealers used their left hand for unscrewing a jartop while only 12.2% of the right handed dealers were left handed in the second activity. The male group using their left hand in card dealing included 77.2% who were left handed for unscrewing in comparison with 13.3% of the right handed card dealers. In the female sample 63.0% of those using her left hand in dealing cards were left handed in unscrewing a jartop, while only 11.2% of the right handed card dealers were left handed for this activity. (table J13abc)

3R.18 Dealing Cards and Threading a Needle

Laterality preference in dealing cards was associated with preference in threading a needle at a very high level of significance in all samples. The left handed card dealing group of the total sample contained 56.3% who were left handed in threading a needle, in comparison with 14.6% of the right handed card dealers. Among the male sample 53.0% of the left handed card dealers were also left handed in jartop unscrewing while only 15.2% of the right handed card dealers were left handed in this characteristic. The left handed card dealers in the female sample included 60.9% who also used their left hand in unscrewing a jartop, but only 13.8% of the right handed girls were left handed for unscrewing a jartop. (table J14abc)

3R.19 Dealing Cards and Use of a Hammer

This pair of laterality variables were very highly significantly associated in each of the three samples. The left handed card dealers of the main sample included 53.6% who were also left handed in using a hammer, but only 2.9% of the right handed dealers were left handed in this activity. Among the males 57.6% of those left handed in dealing were also left handed in hammering, in comparison with 2.4% of the right handed dealers. In the female sample 47.8% of the left handed card dealing girls used their left hand in using a hammer while only 3.4% of the right handed group were left handed for this activity. (table J15abc)

3R.20 Dealing Cards and Using a Racquet

There was a very highly significant association between these two activities in each of the samples. Of the left handed card dealers in the main sample, 50.0% were left handed in use of a racquet, while only 2.9% of the right handed group were left handed for racquet use. Among the males 53.0% of those who used their left hand in dealing also preferred to use a racquet left handed, as compared with only 3.3% of the right handed dealers. In the female sample only 45.6% of the left handed card dealers were left handed in using a racquet, but this figure was still significantly in excess of the right handed group, where only 2.6% were left handed in racquet use. (table J16abc)

3R.21 Dealing Cards and Throwing a Ball

All three samples showed a very highly significant association between laterality preference for dealing cards and for throwing a ball. In the total sample 58.9% of the left handed dealers were left handed in throwing a ball, in comparison with only 3.1% of the right handed dealers. The group of males who were left handed in dealing included 57.6% who were also left handed in throwing a ball, but only 1% of the right handed dealers showed this characteristic. Among the females 60.9% of the girls who were left handed in dealing cards were also left handed in thorwing, as compared with 4.9% of the right handed card dealers. (table J17abc)

3R.22 Dealing Cards and Eye Dominance

Eye dominance was found to be significantly associated with laterality in card dealing in the total sample (at the 0.1% level) and in the male sample (at the 1.0% level). However there was no significant association of the two variables in the female sample. In the total sample 43.8% of those who were left handed in dealing possessed a dominant left eye, in comparison with only 26.6% of those who were right handed. The left handed male group included 47.0% who were also left eyed, while 26.7% of the right handed group were left eyed. In the female sample the difference was less marked. The left handed females included 39.1% who were left eyed, in comparison with 26.5% left eyed among the right handed girls. (table J18abc)

3R.23 Eye Dominance and Kicking a Ball

This pair of characteristics was only significantly associated in the male sample, and there only at the 5% level. There was no significant association in either the total sample or the female sample. In the total sample the left eyed group contained 28.5% left footed kickers and the right eyed group 23.1% left footed kickers. Among the males the difference was more marked, of those boys with a dominant left eye 39.8% were left footed in comparison with 26.8% of those with a dominant right eye. In the female sample there was a higher proportion of left footed persons in the right eyed group than the left eyed group. Only 17.6% of the left eyed girls were left kickers, as compared with 19.9% of the right eyed girls. (table J19abc)

3R.24 Eye Dominance and Stamping Out a Spark

There was a significant association between eye dominance and foot preference in stamping in the male and total samples, but not the female sample. In the left eyed group of the total sample, 33.0% were left footed for stamping, but only 22.1% of those with a dominant right eye showed this characteristic. Among the males the left eyed group contained 43.2% who were left footed while only 24.7% of the right eyed group belonged to this class. The female sample left eyed group included 23.1% who were also left footed in comparison with 19.9% in the right eyed group. (table J20abc)

3R.25 Eye Dominance and Unscrewing a Jartop

In the male sample and the total sample there was a significant association between eye dominance and laterality preference in unscrewing a jartop, but in the female sample the association was not present. The left eyed group in the total sample contained 29.6% who were also left handed, while only 20.4% of the right eyed children used their left hand in unscrewing a jartop. Among the males 39.8% of the left eyed group were left handed, but only 23.0% of those showing right eye dominance used their left hand in unscrewing a jartop. In the female sample the two eye dominance classes contained very similar proportions of left handed persons, 19.8% of the left eyed and 18.1% of the right eyed. (table J21abc)

3R.26 Eye Dominance and Threading a Needle

This pair of variables was only significantly associated in the total sample,and then only at the 5% level. Of the left eyed group in the total sample 28.2% were left handed in threading a needle, as compared with 19.8% of the right eyed group. Among the males who showed left eyed dominance, 30.2% were left handed, while only 21.8% of the right eyed group were left handed. In the female sample 26.4%of the left eyed girls were left handed in threading a needle, in comparison with 18.1% of those who showed right eye dominance. (table J22abc)

3R.27 Eye Dominance and Use of a Hammer

It was found that eye dominance was significantly associated with laterality preference in hammering in all three samples, though the level of significance of the association in the female sample was lower than that in the other two samples. In the total sample 22.5% of those with left eye dominance were left handed in hammering, but only 8.2% of the right eyed group showed this trait. The left eyed male group contained 28.4% who were left eyed, in comparison with 9.5% of the right eyed group. In the female sample the difference was less notable, for here 16.7% of the left eyed girls were left handed as compared with 7.1% of the girls with a dominant right eye. (table J23abc)

3R.28 Eye Dominance and Use of a Racquet

In this case the pattern of association followed that for the preceding pair of variables; eye dominance and use of a hammer. All three populations showed a significant association, but the female sample showed a reduced level of significance. In the total sample 20.1% of the left eyed persons were left handed in use of a racquet but only 8.2% of the right eyed persons showed this characteristic. Twenty-five percent of the left eyed males were left handed in racquet use, in comparison with 10.5% of the right eyed males. Among the females the group with a dominant left eye included 15.4% who were also left handed, while only 6.2% of the right eyed females belonged to this class. (table J24abc)

3R.29 Eye dominance and Throwing a Ball

There was a very highly significant association between eye dominance and laterality preference in throwing a ball in the male and total sample, but there was no significant association in the female sample. The total sample included 22.3% left handed in the left eyed group and 9.8% left handed in the right eyed group. In the male sample 27.3% of the left eyed group were also left handed while only 8.4% of the right eyed group showed this characteristic. Among the females only 17.6% of the left eyed girls preferred to use their left hand in throwing, in comparison with 11.1% of the right eyed girls. (table J25abc)

3R.30 Throwing a Ball and Kicking a Ball

These characteristics were associated at the 0.1% level in each of the samples. Among those who were left handed in throwing in the total sample there were 66.7% who were also left footed, but only 18.1% of those who preferred to use their right hand to throw were left footed. In the male sample 70.0% of the left handed boys were also left footed in kicking, while 24.4% of the right handed boys were left footed. The groups of girls who used their left hand in throwing included 63.4% who also preferred to use their left foot in kicking, while in the right handed girls only 12.7% were left footed.
(tables J26abc)

3R.31 Throwing a Ball and Stamping Out a Spark

Laterality preference for throwing a ball and for stamping out a spark were found to be very highly significantly associated in all three samples. The left handed group of the total sample included 69.1% who were left footed in stamping, while the right handed group contained only 18.5% who were left footed. In the male sample 77.5% of the left handed group used their left foot in stamping, in comparison with 22.7% of the right handed males. Among the females the left handed group contained 61.0% who were left footed and the right handed group included 14.9% who preferred to use their left foot in stamping. (table J27abc)

3R.32 Throwing a Ball and Unscrewing a Jartop

There was a very highly significant association between the laterality preferences for throwing and unscrewing a jartop in each of the three samples. In the total sample 66.7% of those who used their left hand to throw a ball were also left handed in unscrewing a jartop, while only 16.3% of those right handed for throwing were left handed for unscrewing. Of those males that were left handed in throwing a ball, 82.5% were left handed in unscrewing a jartop, in comparison with 19.2% of the right handed ball throwers. Among the females the group preferring to use their left hand in throwing contained 51.2% who were left handed in unscrewing, but only 13.8% of the girls who threw right handed were left handed for the second activity. (table J28abc)

3R.33 Throwing a Ball and Threading a Needle

It was found that there was a very highly significant association between these two characteristics in both the total sample and the single sex samples. The left handed thrower group of the total sample included 70.0% who were left handed in threading a needle, in comparison with the right handed thrower group where only 15.1% used their left hand in threading a needle. In the male sample 71.8% of the left handed throwers were also left handed in threading a needle but only 16.7% of the right handed throwers showed this characteristic. Among the females 68.3% of those who were left handed for throwing were also left handed for threading a needle, while only 13.8% of the right handed throwers used their left hand for this activity. (table J29abc)

3R.34 Throwing a Ball and Using a Hammer

In each of the three samples there was a very highly significant association between laterality preferences for throwing a ball and for using a hammer. Seventy percent of those in the total sample who used their left hand to throw a ball were also left handed in using a hammer, but only 3.5% of the right handed throwers were left handed in this trait. Among the males 85.0% of the left handed throwers were left handed in hammering, as compared with 3.8% of those who threw with the right hand. In the female sample left handed hammer users formed 55.0% of the left handed thrower group and 3.3% of the right handed throwers. (table J30abc)

3R.35 Throwing a Ball and Using a Racquet

Laterality preference in this pair of activities was found to be very highly significant associated in all the samples. The total sample group who preferred their left hand in throwing contained 64.2% who were also left handed in use of a racquet, while only 3.5% of the right handed throwers shared this classification. In the male sample 77.5% of the left handed throwers were left handed for using a racquet, in comparison with 4.6% of the right handed throwers. Among the females 51.2% of the girls who preferred to throw with their left hand also preferred to use a racquet left handed, but only 2.5% of the right handed throwers showed this characteristic. (table J31abc)

3R.36 Using a Racquet and Kicking a Ball

It was found that laterality preference for use of a racquet was very significantly associated with laterality preference in kicking in each of the three samples. In the total sample 78.6% of those who were left handed in using a racquet were also left footed in kicking a ball, while only 17.6% of the right handed group used the left foot for this activity. Among the males 7.8% of the left handed boys were left footed in comparison with 22.6% of the right handed boys. The left handed female group also contained 78.6% who were left footed, while 13.5% of the right handed girls were left footed in kicking. (table J32abc)

3R.37 Using a Racquet and Stamping out a Spark

Laterality preferences for this pair of activities were found to be associated at the 0.1% level in all three samples. The left handed racquet users in the total sample included 78.7% who were left footed in stamping, but only 18.7% of the right handed class were left footed. In the male sample the left handed group contained 83.3% who were also left footed, while 21.3% of the right handed males using their left foot in stamping. Of those girls who were left handed in using a racquet, 64.3% were left footed, in comparison with 16.6% of those girls who were right handed in use of a racquet. (table J33abc)

3R.38 Using a Racquet and Unscrewing a Jartop

The association between these two activities was found to be very highly significant in all three samples. In the total sample 65.7% of those who were left handed in using a racquet were also left handed in unscrewing a jartop, while only 17.5% of the right handed racquet users were left handed for unscrewing. Among the males 66.7% of those who preferred to use a racquet left handed also preferred to use the left hand in unscrewing a jartop, but only 21.6% of the right handed racquet users used the left hand in this activity. The left handed racquet user females included 64.3% who preferred to take off a jartop with the left hand, in comparison with the right handed racquet users, where 14.2% were left handed for unscrewing. (table J34abc)

3R.39 Using a Racquet and Threading a Needle

There was a very highly significant association between laterality preference in using a racquet and in threading a needle. This association was present in all three samples. The left handed racquet users in the total sample included 71.4% who were also left handed in threading a needle, while only 15.5% of the right handed racquet users showed this trait. In the male sample 66.7% of those who were left handed for racquet use preferred to use their left hand in threading a needle in comparison with the right handed racquet users where only 16.4% were left handed for the second activity. Among the females 78.6% of the left handed racquet users were also left handed for threading a needle but only 14.9% of the right handed racquet users showed this preference. (table J35abc)

3R.40 Using a Racquet and Using a Hammer

It was found that there was a very highly significant association between this pair of activities in each of the samples. Of those in the total sample who preferred to use a racquet with the left hand 77.1% were also left handed in use of a hammer. In the right handed racquet user group only 3.8% used a hammer with the left hand. The male left handed racquet user group contained 78.6% who were also left handed in hammering, while only 4.3% of the right handed users of racquets were left handed for this activity. Seventy five percent of those girls who preferred to use a racquet left handed were also left handed in hammering in comparison with only 3.8% of those who used a racquet right handed. (table J36abc)

3R.41 Using a Hammer and Kicking a Ball

In each of the three samples laterality in use of a hammer was associated with laterality in kicking at the 0.1% level. In the total sample 75.7% of those who were left handed in hammering were also left footed in comparison with only 17.4% of the right handed group. The left handed male group included 74.4% who were left kickers, while only 23.1% of the right handed males preferred to kick with their left foot. Among the females left footed girls formed 77.4% of the left handed group and only 12.7% of the right handed group. (table J37abc)

3R.42 Using a Hammer and Stamping Out a Spark

There was a very highly significant association between this pair of activities in each of the three samples. The total sample group who preferred to use a hammer with the left hand included 73.0% who were left footed for stamping, but only 18.5% of the right handed group were left footed. Among the males 81.4% of the left handed boys were left footed, in comparison with 21.4% of the right handed boys. In the female sample 61.3% of the left handed girls were left footed in stamping, while 16.2% of the right handed girls showed this characteristic. (table J38abc)

3R.43 Using a Hammer and Unscrewing a Jartop

All three samples showed a very highly significant association between laterality preference in hammering and in unscrewing a jartop. Of those in the total sample who were left handed in hammering, 71.6% were also left handed in unscrewing a jartop, but only 16.4% of the right handed hammerers showed this characteristic. In the male sample 74.4% of the left handed hammerers were left handed in unscrewing a jartop, in comparison with 20.0% of the right handed boys. Among the females 67.7% of the left handed hammer users were left handed in taking off the top of a jar, while only 13.4% of the right handed hammer user group used their left hand for this activity. (table J39abc)

3R.44 Using a Hammer and Threading a Needle

Laterality preference in hammer use and in threading a needle were associated at the 0.1% level of significance in each of the three samples. In the total sample 68.9% of those who were left handed in hammering also preferred to use the left hand in threading a needle, but only 15.5% of the right handed hammerers were left handed for the second activity. Among the males 65.1% of the group with a preference for the left hand in hammering were also left handed in threading a needle, but in the right handed hammering group 16.9% threaded a needle using the left hand. The female sample included 74.2% who threaded a needle left handed in the left handed hammer group, and 14.4% left handed threaders in the right handed hammering group. (table J40abc)

3R.45 Threading a Needle and Kicking a Ball

This pair of laterality activities was found to be very highly significantly associated in all three samples, though there was rather less marked differences between the groups than had been noted in the preceding association. The left handed group in the total sample included 47.0% who were also left footed in kicking, while only 18.3% of the right handed group were left footed. In the male sample 50.7% of those who preferred to use their left hand in threading a needle were also left footed, in comparison with 24.8% of the right handed group. Among the females 43.1% of the left handed girls were also left footed but only 13.1% of the right handed girls showed this trait. (table J41abc)

3R.46 Threading a Needle and Stamping out a Spark

In the male and total samples these two activities were associated at the 0.1% level, while in the female sample the association was only at the 1.0% level. The left handed group in the total sample contained 41.7% who were also left footed for stamping in comparison with 20.7% of the right handed group. In the male sample 46.3% of the boys who preferred to thread a needle left handed were left footed, as were 25.7% of the right handed group. Among the females 36.9% of the girls who were left handed in threading a needle were left footed whereas only 16.7% of the right handed girls showed this characteristic. (table J42abc)

3R.47 Threading a Needle and Unscrewing a Jartop

There was a very highly significant association of laterality preference in threading a needle and in unscrewing a jartop. This association occurred in both the total sample and in the single sex sample. In the total sample 47.0% of those left handed in threading a needle were left handed in unscrewing a jartop, while 16.1% of those who were right handed for threading were left handed for unscrewing. The left handed threading group in the male sample included 52.2% who used the left hand to take off a jartop, while 20.3% of the right handed threader group used their left hand for this action. In the female sample the group of girls who preferred to thread a needle left handed contained 41.5% who were left handed in unscrewing a jartop, in comparison with only 12.7% of those who were right handed in threading a needle. (table J43abc)

3R.48 Unscrewing a Jartop and Kicking a Ball

This pair of laterality activities was found to be very highly significantly associated in all three samples. The left handed total group contained 44.2% who were left footed for kicking while only 18.8% of the right handed group were left footed. Among the males 44.3% of the left handed boys were also left footed, but only 25.6% of those who used the right hand in unscrewing a jartop were left footed. In the female sample 44.1% of those who used the left hand in taking off the top of a jar were left footed, in comparison with 13.6% of those who were right handed. (table J44abc)

3R.49 Unscrewing a Jartop and Stamping Out a Spark

Once again there was a very highly significant association between the two laterality activities, and this association was present in all three samples. In the total sample 46.4% of the left handed group were left footed whereas only 19.0% of the right handed group showed this trait. The left handed male group contained 48.1% who were also left footed, but only 23.6% of the right handed group showed this trait. The group of females who preferred to unscrew a jartop left handed included 44.1% who were left footed, in comparison with 15.5% of the right handed girls. (table J45abc)

3R.50 Kicking a Ball and Stamping Out a Spark

As might be expected there was a very highly significant association between laterality for kicking a ball and for stamping out a spark. The association was present in each of the samples. The left stamping group in the total sample included 57.6% who were left kickers while only 13.5% of the right stamping group were left kickers. Among the males 63.5% of those who were left footed in stamping were also left footed in kicking, while only 16.6% of the right stamping group were left kickers. In the female sample 50.0% of the left footed stampers were left footed in kicking, in comparison with 11.2% of those who were right footed for kicking. (table J46abc)

3S - Metric Variables

3S.1 Introduction to Metric Varliable Results Section

This section includes data on height, weight, ponderal index, obesity-index, foot length and foot width. The information on these variables from the small Asian and West Indian samples has been included for comparison where appropriate. However in view of the small size of these samples it is accepted that these results may not be of general application.

The metric data was received from the computer in the form of means and standard deviations. These figures were used to calculate values for 't' tests between different population groups. The standard errors of the sample means were also calculated. In order to utilize the chisquare and Kolmogorov-Smirnov tests in comparing metric and non-metric data the continuous range of values in each metric variable was divided into classes. In most cases where a metric variable was associated with a non-metric physical trait the association was examined by both the 't' test and by treating the metric variable as discontinuous. The results of both types of test are reported. Means are corrected to one decimal place, as this is the limit of the accuracy of the measurement methods. This procedure has also been followed for standard errors, except where the corrected result would be zero; in this case one significant figure is used.

3S.2 Metric Variables and Sex Difference

The presence of absence of a significant sex difference for a particular metric characteristic was found to vary in the three racial groups. Heights of the sexes were significantly different in the UK and Asian populations though not in the West Indian group. In the UK sample the mean height of the males was 166.4 cm as compared with 159.0 cm in the females. The mean height of the Asian males was 166.7 cm and the height of the Asian females averaged 154.4 cm. Though the West Indian sample did not show a sex difference in height a similar trend could be seen. The West Indian males mean height was

160.5 cm and the mean height of the female group was 157.2 cm.

There were no significant sex differences in weight in any of the racial groups. The Asian males were clearly heavier than the Asian females, having mean weights of 53.0 kg as compared with 48.6 kg. In the UK sample the sex difference was reduced to one kilogram, males having a mean weight of 53.5 and females 52.5 kg. The West Indian females were found to be slightly heavier than the males. In this group the mean weight of the females was 50.7 kg, but the mean of the males was only 50.1 kg.

In the ponderal index comparisons it was found that there were significant sex differences in the UK and Asian samples but not in the West Indian group. In the UK group the mean ponderal indices were 44.4 in males and 42.6 in females. The comparable figures in the Asian groups were 44.5 in males and 42.4 in females. The sex difference was also present in the West Indian group, though this difference was not significant. The mean ponderal indices in this group were 43.7 in males and 42.6 in females.

The obesity index was found to show a significant sex difference in the UK sample but not in either of the other racial groups. In fact the differences between the sex means in this characteristic are very similar in all groups, but the large sample size and small standard error in the UK group make this result significant. The mean obesity index in UK males was 2.8 while the UK females had a mean of 3.0. The comparable figures for the West Indian sample were 2.8 and 2.9, and in the Asian sample the mean of the males obesity indices was 2.7 while the result for the females was 2.9.

Foot length showed a significant sex difference in all three groups. In the UK sample the mean foot length in males was 25.5 cm but the mean foot length in the females was only 23.7 cm. The West Indian males had a mean foot length of 25.8 cm as compared with 24.2 in the females. In the Asian sample the mean foot length of the males was 25.5 cm while the mean of the females was only 23.4.

Significant sex differences in foot width were present in the UK and Asian samples but not in the West Indian group. In the UK males the mean value was 9.1 cm as compared with 8.4 in the females. The mean foot widths in the Asian sample were 9.2 cm in males and 8.3 cm in females, and the comparative figures for the West Indian group were 9.1 cm and 8.5 cm. (see H7abc, H8)

3S.3 Metric Variables and School Type

It was found that there was a significant difference in height between the selective and non-selective school females. In this comparison the mean height of the selective school girls was 161.0 cm in comparison with 156.6 cm in the girls from the secondary modern schools. However in the males the trend was reversed, though this difference was not significant owing to the high variance of the non-selective sample. The mean height of the grammar school boys was 164.6 cm, but the comparable value for the secondary modern boys was 168.5. Since the trend is reversed in the sexes the results for the total UK sample show an apparent similarity in the mean heights of the children from the two school types. The mean height of the total selective school sample was 162.6 and the mean of the non-selective school group was 162.3.

There were no significant differences between the school types in the weights of the pupils. The children at the non-selective schools were on average heavier than those at the selective schools, and this difference was most marked in the females. The mean weight of the grammar school girls was 53.1 kg, but that of the secondary modern girls was only 51.7 kg. The difference in boys was comparatively slight, the mean weights being 53.7 kg for the grammar schools and 53.2 kg for the non-selective schools. In the total samples the mean weights were 53.4 kg and 52.4 kg respectively.

The mean ponderal index was found to differ significantly between the school types in both single sex samples, but not in the total sample. As in the case of height the trend is in opposite directions in the two sexes, and this results in the difference being effectively cancelled in the total sample. In the males the mean ponderal indices were 43.9 in the selective group and 45.0 in the non-selective group. But in the females the mean ponderal index of the grammar school girls was 43.0 as compared with 42.2 in the secondary modern girls. The mean value for the total sample were 43.4 and 43.5 for grammar and non-selective schools respectively.

The children from the two school types were found to be very similar in their mean obesity indices. In the total sample the mean obesity indices were 2.9 for the selective schools and 2.9 for the non-selective schools. The single sex samples were also similar in their mean obesity index values. The mean value for the grammar school boys was 2.8 in comparison with 2.8 for the non-selective boys, and in the female sample the comparative figures were 2.9 and 3.0.

Mean foot length did not differ significantly between the two school groups. In the total sample the mean foot length of the grammar school group was 24.4 cm while that of the non-selective group was 24.8 cm. The mean values for the male groups were 25.5 cm for the selective and 25.6 cm for the non-selective. A greater difference was noted in the female sample. Here the mean for the grammar school girls was 23.4 cm while that of the non selective girls was 24.0.

There was a slight tendency for the non-selective school sample to possess broader feet, but this difference was not significant. In the total group the mean foot widths were 8.7 cm for the selective school group and 8.8 cm for the non selective schools. The same trend was noted in both sexes. The mean foot width of the grammar school males was 9.0 cm and the comparable result for the non-selective males was 9.2 cm. In the females the mean foot widths were 8.4 cm for selective schools and 8.50 cm for the non-selectives. (tables H3a-f, H6a(ii) - f(ii))

3S.4 Metric Variables and Social Class

In consideration of social class differences it was found that the totals in ScI and SC V were very small. Though results for these classes will be quoted they are thus subject to this limitation. In order to obtain larger class groups for more meaningful comparisons the social classes I and II were summed to form a professional group and the social classes IV and V were combined with the small number of cases with unknown social class to form a manual group.

There were no significant social class differences in the female sample but in the males there were significant differences between the professional and manual groups, between SC I and SC IV, and SC I and SC V. The total sample showed a significant difference between SC II and SC IV. The mean heights of social classes I to III in the total sample were similar being 162.1 cm for SC I, 162.6 cm for SC II and 162.9 cm for SC III. Social classes IV and V were also similar in mean height, the average values being 159.5 cm and 159.3 cm. Among the males there was a difference of 10 cm between the mean heights of SC I and SC V, but these values were for samples of only 6 and 8 subjects respectively. In general the trend was for a reduction of height with reduction of social prestige. The mean height of SC I males was 170.3 cm, of SC II males 164.7, SC III males 168.4, SC IV 162.4 cm and SC V 160.1 cm. However in the females this trend was not noted. Though the mean height of the SC IV females was the lowest value, being only 157.5 cm, the mean height of SC V was 158.7 cm. This value was greater than that of either SC I or SC III where the mean heights were 158.6 cm and 158.0 cm respectively. Though the mean height of SC II females was 159.7 cm none of the class comparisons showed any significant differences. In the combined class groups the mean height of the professional group in the total sample was 162.4 cm as compared with a mean of 161.3 cm in the manual group. The mean height of the professional males was 165.3 cm and the comparable result for manual males was 162.2. However in the females the manual group had an average mean height slightly greater than the professional group, the values being 160.8 cm and 159.3 cm.

Weight was found to be associated with social class among the males but not the females. Among the males there were significant differences between SC I and both SC III and SC V. The professional group males differed significantly from both the middle class and manual groups. In the total sample SC I differed from SC V, and SC II differed from each of SC III, SC IV and SC V. The professional group were significantly different from both the middle class and the manual groups in their mean weights. The mean weights of the social classes in the total sample decreased from SC I to SC V with a total difference of 7 kg between the two extremes. Both the male and female samples showed the same trend. In the males the difference between SC I and SC V was 13 kg, but the difference in the females was only 4 kg. The mean weights in the males were 61.0 kg for SC I, 56.1 kg for SC II, 53.3 kg for SC III, 51.3 kg for SC IV and 47.9 kg for SC V. Among the females the differences were not so marked. The mean weight of SC I females was 53.6 kg in comparison with 53.3 kg for SC II, 51.9 kg for SC III, 52.4 kg for SC IV and 49.5 kg for SC V. In the total sample the mean weights were 55.8 kg for SC I, 54.9 kg for SC II, 52.5 kg SC III, 52.0 kg SC IV, and 48.8 kg in

SC V. In the class group comparisons the mean weight of the total professional group was 55.1 kg as compared with 52.5 kg in the middle class group and 52.4 kg in the manual group. Among the males the mean weight in the professional group was 56.7 kg, the mean of the middle class was 53.3 kg and that of the manual group was 51.3 kg. Though the professional class females were heavier than the middle class females, the manual females were also heavier than the middle class group. The mean weights were 53.4 kg for the professional girls, 51.9 kg for the middle class group and 53.1 kg for the manual girls.

There were no significant differences in ponderal index in either the total sample or the single sex samples. There was no clear trend in the results, In the total sample the mean ponderal index of SC I was 42.6 as compared with 43.1 in SC II, 43.7 in SC III, 43.0 in SC IV and 43.9 in SC V. In the combined groups the total professional mean was 43.0 and the manual group mean was 43.3. Among the males the mean ponderal indices were 43.7 for SC I, 43.4 for SC II, 44.9 for SC III, 44.0 for SC IV and 44.3 for SC V. The mean values for the females were 42.1 in SC I, 42.6 in SC II, 42.5 for SC III, 42.3 in SC IV and 43.5 in SC V.

The obesity index was found to show significant differences in the male sample and the total sample. Among the males SC II and SC III were significantly different in obesity, and the professional males differed from the middle class group. In the total sample SC I was significantly different from SC V, and the professional group differed from the middle class group. There appeared to be a trend towards the reduction of the obesity index with decreasing social status. The mean obesity index of the SC I males was 3.0, in comparison with 2.92 for SC II, 2.8 for SC III, 2.8 for SC IV and 2.7 for SC V. Among the females the situation was less clear. The SC I females had a mean obesity index of 3.1 but the SC V females' mean value was 3.0, and the results for SC II and III were very similar, being 3.0 and 3.0 respectively when corrected. Only SC V girls showed any real difference in obesity, having a mean of 2.8. In the total sample the range between the SC extremes was 0.3 units. The mean obesity index of the total SC I groups was 3.0, while the other results were: 3.0 for SC II, 2.9 for SC III, 2.9 for SC IV and 2.7 for SC V. In the class group comparisons it was found that the mean obesity of the professional groups differed from the other two groups both in the male sample and the total sample. The mean obesity index of the total professional group was 3.0 as compared with 2.9 for the middle class group and 2.9 for the manual group. In the males the mean obesity value for the professional group was 2.9 while the values for the middle class and manual groups were both 2.8. Among the females the results for professional, middle and manual groups were very close, being 3.0, 3.0 and 3.0 respectively, when corrected.

The class comparisons in foot length showed that there were significant differences between SC I and SC V in the male sample and SC II and SC IV in the female sample. In the males there was a decrease in foot length from SC I to SC V. The mean foot length for SC I males was 26.5 cm and the mean foot length for SC V was 25.0 cm.

The mean values for SC II, SC III and SC IV were nearly identical, being 25.6 cm, 25.5 cm and 25.5 cm respectively. Among the females only the SC IV group showed any notable difference in foot length. The mean foot length for SC IV females was 25.0 cm, but the remaining values were 23.5 am for SC I, 23.3 cm for SC II, 23.4 cm for SC III and 23.6 cm for SC V. The greatest mean foot length in the total sample was found in the SC IV. In this group the mean foot length was 25.2 cm as compared with 24.4 cm in SC I, 24.5 cm in SC II, 24.4 cm in SC III and 24.2 cm in SC V. The mean foot lengths in the class group comparisons showed no extreme differences. In the total sample the mean foot lengths were 24.6 cm for the professional group, 24.4 cm for the middle class and 24.9 for the manual group. The mean foot lengths in the males were 25.7 cm for the professionals and 25.5 cm and 25.4 cm for the other two groups. The mean foot length of the manual group females was somewhat greater than that of the other two groups, though this difference was not significant. In this group of girls the average foot length was 24.5 cm as compared with 23.3 cm in the professional group females and 23.4 cm in the middle class.

The foot width comparisons showed that there was a significant difference in foot width between SC I and SC V in the male sample, but not in either the female group or the total sample. In the male sample there appeared to be a trend towards a decrease in foot width from SC I to SC V. The mean foot width of the SC I males was 9.4 cm as compared with 9.1 cm in SC II, 9.1 in SC III, 9.1 in SC IV and 8.8 cm in SC V. However in the females and in the total sample the situation is less clear. In the female sample the mean foot widths were 8.0 cm for SC I, 8.7 cm for SC II, 8.4 cm for SC III, 8.7 cm for SC IV and 8.4 cm for SC V. The total sample results show the same mean value for SC I and SC V, while the maximum mean foot width is found in SC II. The mean of SC I and SC V was 8.4cm while the means of SC II, SC III and SC IV were 8.9 cm, 8.7 cm and 8.8 cm. The class group comparisons showed that in the male and total samples the mean foot width was greatest in the professional class, but in the females the minimum value was found in the manual class. Among the males the professional group had a mean foot width of 9.2 cm as compared with 9.1 cm in the middle class and 9.0 cm in the manual group. The professional class mean in the females was only 8.5 cm in comparison with 9.4 cm in the middle class and 8.6 cm in the manual group. In the total sample the mean foot widths for the professional, middle and manual groups were 8.8 cm, 8.7 cm and 8.8 cm. (tables H1a-f, H2a-f, H5a-f)

3S.5 Metric Variables and Parental Origins

In the comparison of mean height by parental origin it was found that the English group in the total sample were significantly taller than the Midland group. The English group was also taller on average than the British group, though the difference was not significant. The mean height of the English group was 167.3 cm as compared with 162.6 cm for the British and 161.0 for the Midland group. In consideration of the single sex sample it was found that the males showed a difference of over ten centimetres between the

English group and either of the other two groups. This difference was not significant owing to the high degree of variance in height of the English sample. The English males mean height was 175.8 cm in comparison with 162.3 cm in the British and 164.5 cm in the Midland group. Among the females the British girls were the tallest, with a mean height of 162.8 cm. The mean heights of the Midlands and English girls were 158.0 cm and 158.7 cm.

There were no significant differences in the weight comparisons, though the overall trends were similar to those found in the examination of the height data. In the total sample the greatest mean value was found in the English group, which had a mean weight of 53.7 kg. The mean weights of the Midland and British groups were 52.9 kg and 52.1 kg respectively. The English group among the males were also the heaviest, with a mean weight of 54.3 kg, but the Midland males mean value of 53.9 kg was comparatively close to this. The mean weight of the British males was only 50.6 kg. In the female sample the greatest mean weight was found in the British sample, and the Midland girls were the lightest. The values for the Midland, English and British girls was 52.0 kg, 53.2 kg and 53.3 kg.

Ponderal index was not found to be associated with parental origin in any of the samples. As might be expected in a variable derived from height and weight the results seem to follow the general trend of these variables. Among the males and the total sample the maximum mean values were found in the English group, but in the females the class with the greatest mean ponderal index was the British. The mean values in the total sample were 43.1 for the Midland group, 44.5

for the English and 43.6 for the British. Among the males the Midland sample had a mean ponderal index of 43.8 while the English mean was 46.5 and the British value was 44.1. There was less variation among the females. The mean values for the English and the Midland girls showed great similarity, being 42.4 and 42.5, while the value for the British girls was 43.1.

There was no association between the obesity index and parental origin. This variable did not appear to share the pattern of the preceding metric variables. In fact there was a considerable degree of uniformity throughout the sample with respect to this variable. In the total sample the mean values ranged from 2.8 for the British sample to 2.9 for the English and 2.9 for the Midland group. Among the females the Midland mean was 3.0 while the English mean was 3.0 and the British mean was 2.9. The males showed slightly more variation, with a mean obesity index of 2.8 in the Midland group, 2.8 in the English and 2.7 in the British.

The comparison of the mean foot lengths of the three parental origin groups showed that they did not differ significantly. In the total sample the mean foot lengths were 24.7 cm among the Midland group, 24.5 in the English and 24.1 cm in the British. Among the males there was only a difference of 0.2 cm between the two most extreme groups. The mean foot length of the Midland males was 25.6 as compared with 25.4 in the English and 25.4 in the British. The range of the female sample means was slightly greater. In the Midland females the mean foot length was 23.9 cm as compared with 23.6 cm in the English and 23.1 cm in the British.

Foot width showed no significant association with parental origin and there was only slight variation between the groups. In the males the Midland and English groups were found to share the same mean foot width of 9.1 cm, while the mean of the English males was 9.0 cm. In the females the mean foot widths for the three groups were 8.4 cm for the Midland girls, 8.3 cm for the English and 8.6 cm for the British. The total sample means were 8.7 cm in the Midland group, 8.6 cm in the English group and 8.8 cm in the British group. (tables H4a-f, H6a(i)-f(i))

3S.6 Racial Differences in Metric Variables

Though the Asian and West Indian data was somewhat scanty it was thought worthwhile to examine the possibility of racial differences in the metric variables under study. In each of the six metric variables comparisons were carried out between UK and Asian values, UK and West Indian values and between Asian and West Indian results. These comparisons were carried out using the total sample and then repeated using the single sex data; a total of nine 't' test comparisons per metric variable. There were no significant differences between the races in any variable in any comparison. (tables H7, H9)

3S.7 Associations Between Metric Variables

The correlations between the six metric variables were examined both in the total sample and in the single sex sample. The chisquare test was applied to associations between the divided metric characteristics. It was felt that it would be of interest to compare the results of the two measures of association, though it was accepted that correlation was the more legitimate procedure. When correlation coefficients are calculated from large samples it is possible to obtain a high degree of significance even when the actual value of the correlation coefficient is small. In the total sample of 594 correlations coefficients as low as 0.16 were significant at the 0.1% level.

In the total sample height was correlated with obesity, ponderal index and weight with significance at the 0.1% level. The correlation coefficients were 0.93 for ponderal index, -0.29 for obesity and 0.38 for weight. Foot length and foot width were also significantly correlated with height with correlation coefficients of 0.09 and 0.08 respectively. The same relationships were present in the male sample where the correlation coefficients for height were 0.96 for ponderal index, -0.29 for obesity, 0.21 for weight, 0.19 for foot length and 0.13 for foot width. Among the females the significant correlation between height and foot measurements was lacking, but the correlations between height and ponderal index, obesity and weight gave coefficients of 0.83, 0.70 and -0.26 respectively. Obesity was not included in the chisquare tests, but it was found that the divided height was significantly associated with weight, foot width and foot length in both males and females. However the divided ponderal index was only associated with divided height in the female sample.

Weight was found to be associated with height as above, and further significant associations were present between weight and obesity, ponderal index, foot length and foot width. In the total sample correlation coefficients for weight association were 0.62 for obesity, 0.17 for foot length and 0.25 for foot width while there was no association with ponderal index. The correlation coefficients in the males were 0.80 for weight and obesity, 0.52 for foot length and 0.62 for foot width, with no correlation with ponderal index. The female sample showed very significant correlation for both ponderal index and obesity, with correlation coefficients of 0.20 and 0.49 respectively, but there was no association with foot measurements. In the divided metric chisquare tests weight was shown to be associated with ponderal index, foot length and foot width in both sexes.

In addition to the previous associations, ponderal index was shown to be correlated with obesity in the total sample and in both the single sex samples. The correlation coefficients for this association were -0.56 in the total sample, -0.53 in the male sample and -0.75 in the females. Obesity was not included in the divided metric variable chisquares.

Foot lengths showed a significant association with foot width in each of the samples. The correlation coefficients for this association were 0.41 in the total sample, 0.56 in the males and 0.35 in the females. The chisquare tests confirmed that foot length and width were significantly associated in both males and females. In addition to previously mentioned associations, foot width was significantly associated with obesity. This association was present in all three groups. In the total sample the correlation coefficient was 0.16 while in the males the value was 0.43 and among the females the correlation of obesity and foot width was 0.18. (appendix K)

3S.8 Hair form and Metric Variables

Hair form showed an association with height, weight and foot width in males, and with weight in females. The significance or non-significance of the results was to some extent dependant of the form of test applied to the data. When the mean values of the different hair type classes were compared by means of a 't' test it was found that hair type was not associated with height, but hair type and weight were significantly associated in both males and females and the total sample, and there was an association of foot width and hair type in males.

In males the mean height of those with straight hair was 168.7 cm as compared with 164.2 cm in those with a slight wave. 166.7 cm in those with a deep wave and 172.0 of those with curly hair. There was no clear pattern among the females, the corresponding values being 157.0 cm, 160.9 cm, 158.1 cm and 160.7 cm. The combination of these two classes give an apparent homogeneity in the total sample, where the mean height of the straight haired subjects was 162.4 cm as compared with 162.4 cm of those with a slight wave, 162.5 cm in the deep wave class and 163.5 cm in the curly haired class. However when the class distributions are compared by Kolmogorov-Smirnov test (combining deep wave and curly) it is found that among the males both straight and slight wave classes differ significantly from the deep wave plus curly class, the tendency being for the latter class to be taller. In a chisquare comparison of divided height and hair type the same association is found to be present and significant in the males but not in the females. The group of males whose height was equal to or less than 160 cm contained only 5.4% with deeply waved hair, but in the remaining height classes the percentages with this characteristic were 22.8%, 21.0% and 21.9%.

The association of weight and hair form was found by 't' test to be present in both males and females, though the association was more marked in the males. The trend was for increasing weight with increasing degree of hair curl. The mean weight of the straight haired males was only 52.0 kg as compared with 52.9 kg in the slight wave group, 57.9 kg in the deep wave and 67.8 in the curly haired group. Among the females the differences were less notable. The straight haired girls mean weight was 52.0 kg in comparison with 53.8 kg for the slight wave class, 53.2 kg for the deep wave class and 54.4 kg for the curly haired girls. The comparable figures in the total sample were 51.2 kg, 53.4 kg, 55.6 kg and 57.8 kg for the straight, slight wave, deep wave and curly groups respectively. Applying the Kolmogorov-Smirnov test it is found that there are significant differences between the slight wave and deep wave classes in males, and between straight and slight wave in females. The chisquare test also showed significant associations of weight and hair type. In the males both the three class and two class comparisons were significant but in the females the two class comparison was not significant. Only 4.5% of the lowest weight class in males had curly hair in comparison with 24.1% of the top weight group. Among the females the lowest percentage of curly hair was found in the central of the three weight classes.

Hair type was also significantly associated with foot width among the males. The mean foot widths in the male sample were 9.0 cm for the straight haired group, 9.1 cm for those with a slight wave, 9.3 cm for those with deep waves and 9.5 cm for the curly haired group. This trend was not shown by the female sample nor by the total sample. In the females the comparable mean foot widths were 8.4 cm, 8.5 cm, 8.4 cm and 8.2 cm. In the chisquare comparisons foot width and hair type were found to be significantly associated in the males but not the females. Only 9.8% of the straight haired males had a foot width greater than 9.5 cm in comparison with 16.3% of the deeply waved or curly haired and 25.3% of those with slightly wavy hair. The same trend could be seen in the female sample where only 12.5% of the straight haired girls had a foot width greater than 8.5 cm whereas 17.0% and 17.6% of the other two groups fell into this class. When the data was tested by the Kolmogorov-Smirnov test it was found that the distribution of the foot widths of the group containing the curly haired boys and those with deeply waved hair was significantly different both from those with slightly waved hair and from the slightly waved and straight haired groups together. There were no comparable differences in the females when the data was examined by this method. (tables M1, M2, M9, M16, M23, M30)

3S.9 Skin Type and Metric Variables

Skin type showed significant associations with height, weight and foot length in the male sample but in the female and total samples the only comparable association was with weight.

In the 't' test comparisons of the mean heights of the different skin type classes there were no significant differences. However it was noted that the subjects without freckles were taller on average than those with freckles. This trend was present in both the single sex samples and in the total sample. The mean height of the non-freckled males was 170.8 cm as compared with means of 162.5 cm in the lightly freckled and 163.0 cm in the heavily freckled. Among the girls the differences were less marked. The non-freckled girls had a mean height of 160.7 cm whereas the mean of the lightly freckled class was 157.6 cm and the mean of the heavily freckled class was 158.0 cm. The corresponding figures in the total sample were 165.5cm and 160.5 cm. In the chisquare comparison the divided height range was significantly associated with the presence or absence of freckles in males but not in females. In the males with heights of less than 160 cm and 160 to 165 cm the percentages without freckles were 34.4 and 39.7, but in the classes with heights from 165 to 170 cm, and over 170 cm the comparable percentages were 54.8 and 58.7. The Kolmogorov-Smirnov tests showed a significant difference between the distribution of heights of males without freckles and with few freckles, but there were no differences among the females.

The weight comparisons showed that there were significant associations with skin type in both male and female samples, and in the total sample. In the females only the difference between the non-freckled and those with few freckles was significant, but in the males and the total sample the weights of both classes of freckling were significantly different from the non-freckled. The non-freckled were on average heavier than those with freckles. In the males the mean weights were 56.0 kg for the non-freckled, 50.60 kg for the lightly freckled and 52.4 kg for the heavily freckled. Among the females the mean values were 53.9 kg in those with no freckles and 50.9 kg and 52.5 kg for the two grades of freckles. The comparable results for the total sample were 54.9 kg, 50.8 kg and 52.4 kg. When the chisquare test was used the association of divided weight and skin type was found to be significant in the males but not the females. The percentages of males without freckles varied from 31.3% of those in the lightest weight class to 57.9% of the heaviest weight class. In the kolmogorov-Smirnov tests the distribution of the weights of those males without freckles was found to be significantly different from both those with few freckles and those with few or many freckles combined.

Foot length was only significantly associated with skin type among the males. In the 't' test comparison it was found that the mean foot lengths of those without freckles and those with few freckles differed significantly. The mean foot length of the non-freckled males was 25.8 cm as compared with 25.3 cm in the lightly freckled group and 25.5 cm in the heavily freckled males. The same trend was noted in the female sample. Here the mean foot lengths were 23.94 cm in the non-freckled girls and 23.63 and 23.22 cm in the two freckled classes. In the Kolmogorov-Smirnov test a significant difference in distribution of foot lengths was found in the comparison of those with freckles absent or freckles present. The chisquare tests showed that the divided foot length was significantly associated with skin type in the males but not in the females. Of those with a foot length under 25 cm only 36.2% had no freckles, but of those whose foot length was over 26 cm, 58.1% lacked freckles. (tables 1, 3, 10, 17, 24, 31)

3S.10 Weight and Hair Colour

Weight was found to be significantly associated with hair darkness in females but not in males. In the original computer analysis hair redness was also shown by the chisquare test to be associated with weight in males. However checking this result showed that it was not admissible since the test used too many values less than 5. The data was retested using various combinations of figures, and the 't' tests and Kolmogorov-Smirnov tests were also carried out, but in view of the small size of the group with definitely red hair it was not possible to obtain a significantly different result. However it may be worth noting that the proportion of definitely red haired boys with weights less than 45 kg was only 1.5% as compared with 8.9% of those whose weights were between 45 and 55 kg and 2.8% of those with weights over 55 kg. It is possible that the small sample size may account for this apparent variation, since the mean weight of the group with definitely red hair was only 51.6 kg in comparison with 53.6 kg in the slightly red haired group and 53.3 kg in those with non-red hair.

The 't' test comparisons for the weight and hair darkness association showed no significant differences in any sample. In general it appeared that the trend was to increasing weight associated with darker hair. Among the males the mean weights were 51.9 kg in the fair group, 53.7 kg in the light brown, 54.0 kg in the mid brown and 53.9 kg in the dark brown. In the females the comparable figures were 52.7 kg for the fair girls, 51.8 kg for light brown, 53.3 kg for mid brown and 53.3 kg for the dark brown haired. In the Kolmogorov-Smirnov tests the weights of the fair haired girls were found to differ significantly from those of the mid brown and dark brown haired, but no similar result was found in the males. Nor could the association be shown in males by means of chisquare tests, though the females were shown by this method to have a significant association between the two variables. In the female sample it was found that 18.8% of those with weights below 50 kg were fair haired, as compared to only 8.2% of those weighing over 55 kg. The same trend could be seen in the male sample, where 25.4% of those weighing under 45 kg were fair as compared with 18.5% of those weighing over 55 kg. (tables M1, 4, 11, 18, 25, 32)

3S.11 Height and Hair Colour

In chisquare comparisons of chroma and height it was found that these variables were very significantly associated in females but not in males. The significant association was only noted in females when 4 chroma divisions and 3 height divisions were used. Among the females 43% of those in the lowest height division had chroma 1 or 2 as compared with 33.6% of those in the tallest group. Those with chroma of 4 or over formed 25.5% of the shortest group and 23.6% of the tallest girls. (tables M1, 5, 12, 19, 26, 33)

3S.12 Ponderal Index and ABO Secretor

An association between ponderal index and the ABO secretor trait was present in the females but not in the male sample or in the total sample. The mean ponderal indices were not significantly different by 't' test, though the mean ponderal indices of the secretors were higher in both males and females. In the females the mean ponderal index of the secretors was 43.1 in comparison with that of 42.1 in the non-secretors. The mean ponderal index of the male secretors was 44.0 but that of the male non-secretors was 43.6. In the total sample the comparable values were 43.5 and 42.6. When chisquare tests were applied to the data it was found that there was a significant association in the females. In those girls with ponderal index values less than 42 and between 42 and 44 the proportions of non-secretors were 31.8% and 34.0%. However in the group with ponderal index between 44 and 46 the percentage of non-secretors was 18.5 and 19.0% of those with a ponderal index greater than 46 were non-secretors. The Kolmogorov-Smirnov tests showed that there were no significant differences between the ponderal index distributions of either sex. (tables M1, 6, 13, 20, 27, 34)

3S.13 Ponderal Index and Chroma

In the female sample it was found that ponderal index was significantly associated with chroma. The group of females with ponderal index less than 42 was made up of 44.5% chroma 1 or 2, 32.5% chroma 3, 18.3% chroma 4 and 4.8% chroma 5 or more. Of the females with ponderal index over 42, 31.6% had chroma 1 or 2, 47.0% chroma 3, 14.9% chroma 4 and 6.3% chroma of 5 or more. There was no trend towards a similar variation in the males. (tables M1, 7, 14, 21, 28, 35)

3S.14 Height and Finger Length

The comparison of the mean heights of the various finger length groups showed a significant height difference between girls with long index fingers and girls with long ring fingers. The height trends differed in the sexes. In the males those with long ring fingers were taller than those with long index fingers but in the females the situation was reversed. The mean height of the males with long index fingers was 164.1 cm in comparison with 162.9 cm in the equal finger length class and 169.2 cm in the long ring finger class. Among the females the mean height of the long index finger group was 160.8 cm, but the mean of the equal finger length group was 158.5 cm and the mean height of those with long ring fingers was only 156.6 cm. The Kolmogorov-Smirnov comparisons showed that there were no significant differences in the distribution of height in the various finger length classes in either sex. In the divided height range it is noted that in the females the proportion of subjects possessing a long ring finger decreases with increasing height. Only 18.9% of those girls with a height greater than 165 cm had a long ring finger in comparison with 42.2% of those with height less than 155 cm. In the males the situation is reversed, though the difference is not so notable. The tallest height class (over 170 cm) in males contained 53.1% with long ring fingers in comparison with 44.1% in the shortest class with heights less than 160 cm. These associations were highly significant in the female sample when the chisquare test was applied. (tables M1, 8, 15, 22, 29, 36)

3S.15 Metric Variables and Laterality

3S.15a Height and Kick Preference

Kick preference is defined as right, left or either; either means no definite preference. In the 't' test comparison it was found that both the male sample and the total sample showed a significant height difference between right and left, and the female and total samples showed significant differences between the right and either groups. In examination of the mean height values it can be seen that the left kicking males are on average taller than the right or undecided kickers. The mean height of the left footed males was 180.1 cm in comparison with 163.6 cm for those in the undecided class and 164.7 cm in the right footed group. In the females the mean height of those kicking with either foot was 167.9 cm whereas in the left footed group the mean was 158.7 cm and in the right footed group the mean height was 158.9 cm. The total sample mean heights showed an apparent decrease of height from left to right footedness. The mean height of the left-footed total was 170.4 cm, in the group without a dominant foot the mean was 165.3 cm and the mean of the right footed group 160.84 cm. In the chisquare comparison it was found that height was significantly associated with kicking preference in males, though not in females. The proportion of right footed males varied from 59.1% in those with heights less than 160 cm, to 79.0% in the class with heights between 165 and 170 cm. In the females the variation of proportions of right footed only varied between 77.3% and 84.0%. There was no significant difference between the groups by Kolmogorov-Smirnov test. (tables N5, 16, 27, 1, 2, 4)

3S.15b Ponderal Index and Writing Preference

There was no significant difference between the mean ponderal indices of the writing preference classes, though the right handed group had slightly greater ponderal indices in each case. In the males the mean ponderal indices were 43.4 in the left handed group and 44.6 in the right handed group. The difference in the female group was smaller. The mean ponderal index of the right handed girls was 42.6 in comparison with 42.2 in the left handed group. In the total sample the means were 42.9 in the left handed and 43.5 in the right handed. The Kolmogorov-Smirnov tests showed that the distribution of ponderal indices differed significantly in the male writing preference classes, though not in the females. The chisquare test was also significant in the males though not in the females. Of the males with a ponderal index below 44, 18.4% were left handed but in those with a ponderal index greater than 44 only 7.4% were left handed. The same trend could be detected in the female sample, where 11.4% of the class with ponderal index below 42 were left handed, in comparison with 7.6 of the remainder of the sample. (tables N1-3, 7, 18, 29)

3S.15c Ponderal Index and Hammering Preference

The result for hammering preference appear to follow those for the association of ponderal index and writing. None of the 't' test comparisons were significant, though the mean ponderal indices of the right handed group were greater in each group. The mean ponderal index of the left handed males was 43.3 as compared with 44.6 in the right handed group. In the females the mean ponderal indices were 41.7 in the left handed and 42.7 in the right handed. The total sample means were 42.6 for the left handed group and 43.6 for the right handed group. The Kolmogorov-Smirnov tests showed significant differences between right and left handed males but the comparison was not significant in females. In the chisquare test there was a significant difference in the male sample but not in the females. Examination of the divided ponderal index data showed that 22.7% of the males with a ponderal index less than 44 were left handed in use of a hammer, in comparison with only 8.1% of those who were right handed. In the female group the difference was also present though not as extreme. In the group with ponderal indices less than 42 14.5% were left handed as compared with 6.6% of the remainder of the sample. (tables N1-3, 8, 19, 31)

3S.15d Weight and Laterality Variables

A total of eight of the ten laterality variables showed a significant association with weight. In two cases the association was present in both sexes and in the remaining six variables the association was found in the female sample alone. (tables N1-4)

3S.15c Weight and Card Dealing Preference

This association was not found to be significant when the mean weights of the laterality classes were compared. It was noted that the mean weights of the subjects who used their left hands for dealing cards were greater than those of the right handed. In the males the mean weight of the left handed was 54.7 kg in comparison with 53.1 kg in the right handed. The mean weight of the left handed females was 53.4 kg but that of the right handed was only 52.3 kg. The total sample means were 54.2 kg in the left handed class and 52.6 kg in the right handed class. In the Kolmogorov-Smirnov tests there was no significant difference between the laterality classes, but when the data was tested in a chisquare contingency table it was found that the females showed a significant association of weight and card dealing laterality. Only 10.6% of the females with weights under 50 kg were left handed as compared to 24.7% of those with weights between 50 and 55 kg. However the proportion of left handed girls in the greatest weight class, over 55 kg, was only 13.0%, so the relationship is not a simple one. In the males the median weight class, containing males with weights from 50 to 55 kg, contained only 17.0% left handed subjects in comparison with 23.9% of those with weights less than 50 kg and 29.9% among those with weight over 55 kg. (tables N9, 20, 39)

3S.15f Weight and Eye Dominance

In contrast to the majority of the metric/laterality associations found in the survey, the relationship between weight and eye dominance is more strongly expressed in males than in females, though both are significant. The 't' test comparisons show significant differences in both sexes. In the males the right eyed group was heavier than the left eyed class. The mean weight of the right eyed males was 54.6 kg in comparison with 51.1 kg in the left eyed males. But in the females the position was reversed and the left eyed females were heavier than the right eyed group. The mean weights in this case were 54.8 kg for the left eyed girls and 51.5 kg for the right eyed group. This difference is cancelled out in the total sample where the mean weights of right and left respectively were 53.0 kg and 53.0 kg. The Kolmogorov-Smirnov test showed no significant differences between the right and left groups, but in the chisquare tests it was found that the males showed a significant association of weight and eye dominance. In the lowest weight group 37.3% were left eyed but in the highest group only 22.2% had a dominant left eye. Among the females 24.1% of the lowest weight group and 36.4% of the highest weight group were left eyed. (tables N10, 21, 32.)

3S.15g Weight and Ball-throwing Preference

Neither the Kolmogorov-Smirnov tests nor the 't' test comparisons gave any significant differences between the laterality groups in throwing a ball. The mean weight of the right handed males this trait was in fact lower than that of the left handed males, being 53.4 kg in comparison with 55.9 kg. In the females the right handed group was heavier than the left handed group though the difference between the group mean was comparatively slight. The mean weight of the left handed females was 52.1 kg in comparison with 52.5 kg in the right handed females. The total sample means were 53.2 kg for the left handed and 52.9 kg for the right handed. In the chisquare comparison it was noted that there was a very significant association between weight and ball throwing laterality. As in the previous section the greatest frequency of left handed girls was found in the median of the three weight classes where 24.7% were left handed in comparison with 10.5% and 8.2% of the other weight classes. The males showed a lower frequency of left handed subjects in the central weight class, where only 10.8% were not right handed, though 16.4% and 16.7% of the other two classes were left handed. (tables N11, 22, 33)

3S.15h Weight and Racquet Using Preference

There were no significant differences in weight associated with the different laterality classes when the data was examined by 't' test and by Kolmogorov-Smirnov test. The mean weight of the left handed males was slightly greater than that of the right handed racquet users, being 54.0 kg in comparison with 53.4 kg. Among the females there was less difference in the means and the mean weights were 51.1 kg for the left handed and 52.5 kg for the right handed. Despite this apparent homogeneity, the chisquare tests showed a significant association of weight and racquet holding laterality in the female sample. Again the greater frequency of left handed users was found in the median of the three weight divisions, with reduced frequencies in the two extremes. In the weight group containing those girls with weights between 50 and 55 kg, 19.2% were left handed, but in the groups with weights less than 50 kg and greater than 55 kg the proportions of left hand users were 6.0% and 5.5% respectively. As in previous sections it was noted that the median weight class of males showed a deficit of left handed racquet users in comparison with the other two weight groups. Only 10.8% of the median group were left handed in comparison with 16.7% and 18.5% of the two extreme groups. (tables N12, 23, 34)

3S.15i Weight and Hammer Use Preference

The 't' test comparison between the laterality classes in hammering laterality were not significant. The left handed hammer users were on average heavier than the right handed group. In the left handed males the mean weight was 54.1 kg in comparison with 53.4 kg in the right handed. Among the females the mean values were 54.7 kg in the left handed and 52.2 kg in the right handed. The total sample values were 54.5 kg and 52.7 kg. In both the Kolmogorov-Smirnov tests and the chisquare tests weight was found to be significantly associated with hammering laterality in females but not in males. Among the females only 3.8% of those in the lowest weight class were left handed, in comparison with 22.2% of those in the median weight class and 9.1% of those in the heaviest group. As in previous sections the lowest frequency of left handed males was found in the median weight group, where only 11.9% belonged to this group. The two more extreme weight classes the proportions of left handed subjects were 14.9% and 19.4%. (tables N13, 24, 35)

3S.15j Weight and Needle Threading Preference

This association was not found when the mean weights of the laterality classes were compared by 't' test. Though the mean weights of the right handed needle threaders were in each group greater than the left handed sample these differences were slight. In the males the mean weight of the left handed group was 52.8 kg in comparison with 53.7 kg in the right handed group. Among the females the mean weights were 52.4 kg and 52.7 kg respectively, and in the total sample the mean weight of the left handed was 52.6 kg while the mean of the right handed was 53.0 kg. There was no significant difference in the Kolmogorov-Smirnov comparisons but in the chisquare test it was found that divided weight was significantly associated with needle threading laterality in females, though not in males. In the females the median weight group contained 31.5% left handed girls in comparison with 18.8% and 15.5% of the low and high weight classes. (tables N14, 25, 36)

3S.15k Weight and Jartop Unscrewing Laterality Preference

The 't' test comparisons of the mean weights of the laterality classes showed no significant differences in weight, though the left hand users were slightly heavier in the male and the total sample. The mean weight of the left handed males was 54.3 kg in comparison with the right handed group's mean of 53.1 kg. In the females the mean weights were 52.3 kg for the left handed and 52.5 kg for the right handed. The total sample means were 53.5 kg for the left handed jartop unscrewers and 52.8 kg for the right handed group. When the Kolmogorov-Smirnov tests were applied to the data there were no significant differences but in the chisquare comparisons a significant association of weight and jartop laterality was present in the female sample. The median weight class contained 31.5% left handed girls, but only 14.3% of the low weight group and 17.3% of the high weight group were included in the left handed group. In the males there appeared to be a trend to increasing proportion of left handed persons with increasing weight. The proportions of left handed males in the three weight classes were 22.4%, 26.5% and 34.3% in order of weight magnitude. (tables N15, 26, 37)

3S.151 Weight and Kicking Preference

In this association there were no significant 't' test values in either sex. The mean weights in the different laterality classes showed little pattern. In the males the mean weights were 52.8 kg for left footed, 53.7 kg for uncertain laterality and 53.5 kg for the right footed. The comparable results in the females were 52.4 kg, 54.9 kg and 52.2 kg. In the total sample the weight mean of the left footed group was 52.6 kg in comparison with 54.3 kg in the undecided group and 52.8 kg in the right footed group. However when the data is examined by chisquare and Kolmogorov-Smirnov tests it is found that though the Kolmogorov-Smirnov test shows no significant association, the chisquare test is significant in both sexes. As in many of the previous weight laterality associations this significance appears to be due to an excess of left (or undecided) footed females in the median weight group and a deficit of left footed males in the comparable group. In the females 31.5% of the median group were left footed as compared with 14.3% and 17.3% in the other two groups. Only 21.6% of the male median weight group were not right footed, but 40.3% of the lightest group and 34.3% of the heavy group were classified as left footed or of undecided laterality. (tables N6, 28, 17)

4 TWIN SURVEY

4A Introduction to the Twin Survey

Since the twin survey forms a finite unit within the main body of the project it has been decided to report it as such. An alternative procedure would have been to scatter the data through the relevant sections, so as to give a direct comparison of heritability results and survey results. However it was felt that in this case the direct comparisons between the heritabilities of the various traits would be of value.

4B Twin Survey Methods

4B.1 Background of Twin Survey

From the outset of the project it had been intended to undertake a twin survey. All of the traits under study were known to be at least partly determined by hereditary factors but there were no known estimates of their heritability. The accepted method of determining the heritability of a characteristic is to compare the intra pair variation in monozygotic and dizygotic twins (Osborne and de George, 1959, Shields, 1963).

4B.2 Collection of Adult Twin Sample

Early in 1968 Rediffusion Television Ltd. broadcast a programme devoted to twins. In this programme the television company had collected a large number of adult identical twin pairs to form the studio audience. At this stage of the survey it was still hoped to use adult subjects, and so this programme offered an opportunity to contact a large group of twins.

When Rediffusion were contacted it was learned that several other bodies were interested in using the twins. The television company were not prepared to reveal the names or addresses of their twin sample, but they offered to hire a mailing firm to pass on to the twins a combined package of requests from all the interested parties. Costs were to be shared by the participants.

A total of 650 twin pairs were to be included in the scheme. Accordingly this number of letters to the twins were prepared and sent to Rediffusion. The letter asked the twins whether they would be willing to participate in a future survey. A reply slip was attached to the bottom of the letter and a reply paid envelope was provided for the return of this slip to the University.

Replies were received from 146 pairs of twins. Of these two-thirds were female, and the majority were resident in or around London. There were no twins from Birmingham and very few from the Midlands as a whole. In view of this geographical distribution it was at that time impossible to use the twins. The cost of bringing them from London to Birmingham could not be afforded. It was impossible to go down to London for any long period as the main survey arrangements were under way. Even if it had been possible to set up a centre in London the travel expenses of the twins would still have had to be met and as most were employed adults they would either have had to be seen in their leisure time or else compensated for loss of work time. The project was therefore temporarily abandoned

4B.3 Collection of School Twin Sample

During the course of the main survey (1968 to 1969) a number of pairs of twins were encountered. It was decided to see whether a numerically worthwhile sample of local twins of secondary school age could be collected. Enquiries were sent to all the city grammar, bilateral and comprehensive schools. (See specimen letter 01). The bias towards the more able twin pairs was deliberate as it had been noted in the main survey that the less able children needed more time for the interview and that they were in general more passive in their reaction to the survey. Since the twin survey was to include an extended practical section on laterality it was necessary that the twins be willing to participate in this without anxiety.

Replies were received from 34 of the 46 schools approached. Two schools had no twins at that time but the remaining 32 were willing to help in finding twins. An explanatory letter to the twins had been prepared with a detachable reply slip requiring their parents' signature giving consent for them to take part in the survey. These letters were sent to the twins together with a reply paid envelope. In some cases the head teachers sent a list of names and addresses of twins to the University and in some cases they preferred to be given the stationery and contact the twins themselves. Xerox copied posters advertising the survey were also sent to the schools if required (see specimen copies 02a, 03).

A fee of 10/- (50p) per twin was offered, and the survey was timed to take place during the school holidays. The initial total of twin pairs with their parents' consent was 70. At this stage it was found that it was going to be possible to check the twins' zygosity by blood grouping. A second letter was therefore sent out explaining that a blood sample was required and giving the twins a definite appointment and a map showing the location of the University. This letter also had a reply slip which was to confirm the appointment and obtain parental consent for the blood sample. Only 58 of the twin pairs were prepared to give blood samples. (see speciment letter 02b)

4B.4 Survey Arrangements

The twins were interviewed during the period of August 4th to August 28th, 1969. These dates were fixed on the one hand by the attendance of the interviewer at a conference in the second half of July and on the other by the end of the school holidays. It was decided that four pairs of twins would be the maximum number that could be interviewed in one day. Each set needed one hour for the actual interview and it was thought important to allow an interval between the appointment times since it was expected that some would arrive late and some early. The appointments were set for 10.00 am, 11.30am, 2.00pm and 3.30pm. This allowed a 30 minute interval between the twin sets. The appointments could have been started earlier in the morning but it was felt that this might have caused domestic inconvenience to those mothers who wished to accompany their twins to the University. In assigning the appointment the 10.0am and 3.30pm appointments were generally given to the older twin pairs who were most likely to come to the University without their parents. It was necessary to take into account the holiday dates of the twins when fixing the appointments. The twins had been asked to give dates when they would not be available on the first reply slip.

Since there were originally 70 pairs of twins this meant that appointments were spread over 3½ weeks. It was felt that appointments should not be cancelled even if the twin pairs did not respond to the second letter giving details of the appointment. The experience of the main survey had shown that official letters and forms were often mislaid. In fact several pairs of twins did arrive without having confirmed the appointment, bringing their parents' consent forms with them as they had lost the reply paid envelopes. Some pairs were unable to attend owing to illness and had to have new appointments given to them. In general the twins were punctual, though some arrived very early and one pair rang the University at the time of their appointment to say that they had overslept and that they would be coming as soon as they could. On average three pairs of twins were seen each day, a total of 58 pairs.

4B.5 Interviewing Arrangements at the University

During the interview period assistance was given by Mr. J.G. Cleather, a final year student in the Department of

Biological Sciences at Aston. Mr. Cleather was collecting data for a final year project on laterality in twins.

When the twins arrived, some with a parent or parents and some with their whole family, they were introduced to the investigator and Mr. Cleather. Usually the twins were able to find their own way to the laboratory where the survey was taking place, but some preferred to be collected from the Enquiries Desk at the University entrance. In the letter giving the twins their appointments the room number had been given, and also the telephone extension so that the twins could ask the Enquiries desk to contact the investigator to inform her that they had arrived. Only one pair of twins went astray; these were misdirected to the Applied Psychology Department and were speedily retrieved.

The twins were arbitrarily designated Twin A and Twin B. Twin A was taken to the main laboratory where the non-laterality variables were noted. Twin B accompanied Mr. Cleather to another laboratory where a series of laterality tests were carried out. When the investigations were complete Twins A and B were exchanged, and Twin B did the non-laterality survey while Twin A did the laterality tests. Twin A and Mr. Cleather then returned to the main laboratory, where the twins were photographed together.

Side and full face views were taken of the twins standing together against a white backcloth. The photographs were taken using an Asaki Pentax Reflex Camera with an f 1.9 lens, mounted on a Rowi Heavy Duty Tripod. Illumination was provided by Photo flood bulbs. Kodak Tri-X Pan film was used. The subject to camera distance was approximately twelve feet. This was not standardized as it was not intended to use the photographs for accurate measurements.

When the photographs had been taken the twins were given their fee. They were asked to sign for this to comply with the University Finance Department regulations. The first forty pairs' fees were paid by the Department and the remainder of the fees were paid by the Medical Research Council.. The twins were then taken down to the University Health Centre where the sister in charge took a 5ml sample of venous blood from their arms. In six cases it was only possible to obtain a blood sample from one of the pair. Two of these were cases where the child decided at the last moment that they did not want to give the sample, but in four cases the sister could not obtain a sample as the vein collapsed. (These latter cases were later contacted again, but only one was willing to have another attempt made to take his blood. The investigator took the University sister out to his home in an evening visit, but it was not possible to obtain any blood.) After the blood sample had been taken the twins left the University. Only in one case did a child show any adverse reaction to the blood sample being taken. This was in an eleven year old boy whose twin refused to give any blood. Both had been very apprehensive about the whole survey although accompanied by their mother, and it was suggested by the investigator that it might be better not to attempt to take any blood from them. However the twins' mother felt that they should give full value for their fees and so persuaded one twin to give a blood sample, stating that she would obtain the other twin's blood sample via the family doctor.

Unfortunately the boy later felt faint but soon recovered after lying down in the Health Centre. A second blood sample was not received so it was assumed that the mother's attitude had softened.

4B.6 Zygosity Determination

The most reliable method of diagnosis of the zygosity of a twin pair is to obtain a blood typing for each twin, including as many blood group systems as possible. From this data it is possible to calculate the exact probability of the twins being monozygotic (MZ) if the parents are also blood-typed (Maynard-Smith and Penrose 1954). The population blood group frequencies can be used instead of the parental values. Wyslouchowa and Orczykowska (1969) state that the two types of twins can be diagnosed with an accuracy of 99.6% if three plasma factors are used with six blood group systems. Cederlof and co-workers (1961) found that 96% of their twin sample was correctly diagnosed by accepting as MZ those who were concordant for the ABO, Rh and MN systems, haptoglobin and the GM factors. Jarvik and fellow workers (1969) have suggested a further immunological method for twin diagnosis when the blood groups are concordant, but this involves cell culture. In a comparison of the use of anthropological traits and blood groups in zygosity determination, Dencker and co-workers (1961) found that blood groups alone would sort 95% of the twin pairs correctly.

Another method of twin diagnosis is to compare the dermatoglyphics of the twins. The dermatoglyphics of MZ twins tend to be very similar, though the patterns are sometimes reversed, whereas those of DZ twins show only fraternal similarities. Rife (1938) found that dermatoglyphics were useful in twin diagnosis, however the problem is one of defining the point of division between MZ and DZ twin pairs. Shields (1962) used a discriminant calculated from finger prints and found that this was not entirely satisfactory. Slater (1963) has modified the discriminant with some success. However a later attempt to provide a quadratic discriminant (Slater et al 1964) proved to be no more successful than the version of 1963. Slater et al concluded that "there may be an irreducible area of uncertainty in the application of fingerprint analysis for zygosity diagnosis; that in fact a significant proportion of DZ twins resemble one another as much as the majority of MZ twins".

A third method of twin diagnosis is the use of anthropological variables. Dencker et al (1961) found that such characteristics could never definitely diagnose dizygosity, and that uncertain cases were usually shown by blood grouping to be MZ. However when it is not possible to obtain blood samples or fringer prints from the twins such a diagnosis using external characteristics can be valuable (Ardashnikov et al 1936). In some surveys information as to whether the twins have been visually confused by friends and family have been used (Nichols and Bilbro 1966). Cederhof et al (1961) found that 71 of 72 pairs of MZ twins reported being mistaken for each other as children. Nichols and Bilbro (1966) used height weight hair colour and eye colour in an attempt to specify rules for diagnosing zygosity for questionnaire items, and found that 95% of the cases could be diagnosed with a 90% accuracy. They suggest that the addition of ear lobe type and mid-digital hair would increase the accuracy of the method. In an ingenious method devised by Sammalisto 1961 the survey twins were given scores for photographic similarity, height, weight, eye colour, hair colour, baldness, skeletal type and extent of confusion by acquaintances. Only those twins whose scores were intermediate were blood typed. Since Sammalisto's sample were scattered throughout Finland this was a considerable saving of time and expense. Newman (1928a) put forward a list of 15 traits to be considered in twin diagnosis, some of which might not be considered in a modern survey. Recently Gaines and Elston (1969) proposed that the probability of a twin pair's monozygosity could be determined graphically, provided that a trait occurring in two alleles at a single locus was used, and that the gene frequency of the trait was known.

4B.7 Blood Typing of Present Twin Sample

When the twin survey was planned negotiations were started with the local Blood Transfusion Centre as it was thought possible that they might be willing to type the blood samples, either at the time of the twin survey or at some future time (it would have been possible to obtain the blood samples from the twins at a second visit if necessary). However they replied that they were unable to do this as they were already involved in the Birmingham twin survey organised by the Children's Hospital. The Birmingham Twin Survey had been running for nine years at that time. Its very worthwhile function is to collect details of all twins born in Birmingham. Thus at the time of this survey the eldest children were only 9 years old.

It had been considered whether these twins could be used in the present survey instead of collecting another sample, but it was decided that they would be too young to be properly compared with the main survey sample who were 14 or 15 years old.

When the reply was received from the Blood Transfusion Service the Birmingham Twin Survey organisation were contacted as it was thought possible that they might wish to include this small sample of older twins in their main group. It was stressed that the collection of this twin sample was in no way intended as an act of piracy, but was merely necessary because of the age difficulties. However, the Birmingham Twin Survey still felt that the present survey twins should not be blood tested by the Birmingham Blood Transfusion Centre, though they saw no reason why this lack of zygosity diagnosis should hamper the survey.

These negotiations had occupied a considerable period. When the final refusal was received it was decided to contact the National Blood Group Reference Laboratory in London. Although the request for zygosity diagnosis was made at very short notice the Director of the Laboratory at once agreed to do the blood typing.

The blood sample from each twin was put from the syringe into a 10 ml blood sample bottle without anticoagulant. Each bottle was labelled with the department and university, and the twin's identification number. All the blood samples from the day's twins were packed securely in cotton wool in a cardboard box after the last twin pair had left. This box was therefore sent off to the Blood

Group Reference Laboratory by First Class Post within hours - approximately seven hours - of the first sample being taken.

The blood samples were typed at the Reference Laboratories for the ABO, Rhesus, MNS, Lewis, Lutheran, Duffy, Kell and P systems. Records of the blood group were periodically sent back from the Reference Laboratories. When these results were received the blood groups were copied out on to a certification which was sent to the twins. It was hoped that they would keep the certificate in case they were at some future time involved in another twin survey. This would save them the necessity of being blood typed again (see certificate 02c).

4B.8 Diagnosis of Zygosity by Finger Prints

It was realised at the start of the project that it was likely that some twins would not or could not provide blood samples. It was therefore decided to take the finger prints of all the twins as a safeguard, so that these finger prints could be used to diagnose those twins for whom blood data was not available.

4B.9 Method of Obtaining Finger Prints

The Kleen-Print system was used. This involves sensitised record sheets, which in this case had marked spaces for prints from each finger (and thumb). The print is made by rolling the finger on a pad which has previously been moistened with a special fluid. The finger is then rolled on the sensitized paper, and a print of the finger developes, grey in colour. The advantage of this system is that it leaves the subjects' hands comparatively clean. The 'ink' leaves no mark at all on the hands.

The twins were asked to wash their hands before starting to do the printing. The purpose of this was to remove the grease from their fingers. It is possible to take finger prints by the investigator rolling the subject's fingers while they remain passive. This procedure was used in some cases, but usually it was found that the twins were able to produce their own prints after the method had been demonstrated.

The clarity of the print depends on the appropriate amount of ink and pressure being used. The prepared paper has a shiny surface and it was easy to skid and spoil the prints. In some of the younger twins it was difficult to obtain clear prints as they appeared to have very soft finger-tips. This part of the survey proved very popular with the 11-12 age group, and those who showed interest were allowed to make spare sets of prints to take home.

4B.10 Calculation of Zygosity from Finger Prints

This method was only used in the twin pairs from whom blood data was not available, as the blood group method is more accurate. Slater (1963) describes a method of discriminating between MZ and DZ pairs on the basis of their total ridge counts and individual finger ridge counts. It was decided to apply this method to the six pairs in question.

Slater modifies the method used by Holt (1952) in making a ridge count. He counts the number of ridges that cut or touch a straight line running from the tri-radius to the centre of the pattern plus one of the end points. Holt excludes both the centre and the tri-radius from the count. Since there is a possibility of a ridge count on both the ulnar and radial side of each finger, Slater notes all 20 possible ridge counts for each individual. These figures are then used to calculate two factors S and T.

To calculate S the 20 ridge count differences are expressed in the form d: = $\log_{10}a_1 - \log_{10}b_1$ where a_1 is the first single ridge count for Twin A and b_1 is the same figure for Twin B. The ridge counts are all increased by one before the logarithmic values are taken. This avoids the situation where $a_1 = 0$ (or $b_1 = 0$). S is then the sum of d_1 to d_{20}.

T is calculated from the total ridge counts of each twin. If A is the sum of the 20 single counts of Twin A and B is the sum of the 20 single counts for Twin B, $T = \log_{10}A - \log_{10}B$.

In the original method used by Shields (1962) the values of S and T were substituted in the expression $L = S+12T-6$. However, Slater (1963) suggests that $Z = \log_{10}(S + 30T)$ gives better discrimination between MZs and DZs, beside other advantages. He also gives a table of probabilities of monozygosity or dizygosity for different values. It was decided to use Slater's discriminant in the present diagnosis.

<u>4B.11 Methods for Non-Laterality Variables</u>

The same non-laterality variables were studies as were included in the main survey. In all cases the methods and apparatus used were those used in the main survey. It is therefore not necessary to repeat the details in this section, but the references to the appropriate sections are given below.

The procedure in this section of the twin survey was identical to that of the main survey, except for the addition of fingerprinting. The collection of finger prints was added as the last item in this part of the survey.

Methods:	<u>Eye Colour</u> :	Section 2G
	<u>Ocular Defects</u> :	Section 2I
	<u>Colour Vision</u> :	Section 2H
	<u>Hair Colour</u> :	Section 2J
	<u>Hair Form</u> :	Section 2K
	<u>Hair Line</u> :	Section 2L
	<u>Skin Type</u> :	Section 2O
	<u>Ear Type</u> :	Section 2M
	<u>Chin Type</u> :	Section 2N
	<u>Finger Length</u> :	Section 2Q
	<u>Mid-Digital Hair</u> :	Section 2P
	<u>Secretor</u> :	Section 2S
	<u>PTC</u> :	Section 2R
	<u>Height</u> :	Section 2U.1
	<u>Weight</u> :	Section 2U.1
	<u>Ponderal Index</u> :	Section 2U.3
	<u>Obesity Index</u> :	Section 2U.3
	<u>Foot Length</u> :	Section 2U.2
	<u>Foot Width</u> :	Section 2U.2

4B.12 General Background Laterality Testing

A discussion of the methods of investigating laterality differences is given in the Methods section of the main survey (see Section 2T.5). This will not be duplicated in this part of the survey.

4B.13 Expansion of Laterality Investigation in Twin Survey

It was previously noted that it was preferable to test the laterality of the subjects in a practical situation rather than rely on their reported behaviour in a questionnaire investigation. In the main survey it was not possible to undertake a full investigation owing to the limitations of time available for each subject's interview. If assistance had not been available for the twin survey it would not have been possible to extend the laterality section.

As previously mentioned a final year student Mr. J. Cleather gave assistance during the actual period of the twin survey and was responsible for administering a series of practical tests of laterality. The range of laterality tests had been decided by discussion between the investigator and Mr. Cleather so as to include all the activities required for the present survey while still allowing Mr. Cleather to collect some extra data solely for his own use. Mr. Cleather also made use of some of the data that is included in this report, interpreting it according to his own hypotheses. Although the laterality tests on the twins were not in general performed in the presence of the investigator it was believed that the testing was conscientiously carried out. In the case of two twin pairs where there was a time lag it was possible for the investigator to watch as Mr. Cleather tested the twins and it was found that he was following the procedure that had been agreed upon.

4B.14 Activities Included in Twin Survey

Eleven activities involving the use of the hands were included in the survey. Of these grip strength and tapping speed were numerical variables, while the remaining nine involved classification into right or left hand use for that task. Of these nine tasks five were unimanual (writing, throwing a ball, hammering a nail, using scissors and reaching up for an object) while the rest were bi-manual (unscrewing a jartop, threading a needle, striking a match and dealing cards).

Three tests involved eye usage, these were sighting a rifle, sighting through a tube and viewing a kaleidoscope. In order to test ear preference one test of listening to a clock was included, and foot preferences were tested in hopping, stamping and kicking.

In an attempt to estimate whether the twin pairs were manifesting any signs of situs inversus their hair whorl position and the side having a larger thumb were noted.

4B.14a Writing

The subject was asked to write his or her name and address on the test form and the hand used was noted.

4B.14b Throwing Ball

A ball was provided which the subject had to remove from a large jar by unscrewing the top. The subject was then asked to throw the ball to hit a target on the wall.

4B.14c Hammering Nail

A piece of wood with a nail partly imbedded in it was provided and the subject was asked to hit the nail with a hammer which was laid on the bench beside the wood.

4B.14d Using Scissors

A piece of paper and a pair of scissors were provided, and the subject was asked to cut the paper in half. The scissors were of the normal right-handed type. Both the paper and the scissors were laid out on the bench for the subject to pick up as he or she wished.

4B.14e Reaching Up for an Object

A piece of chalk was placed on the top of the door frame and the subject was asked to reach up and try to bring it down.

4B.14f Unscrewing a Jartop

The ball for the throwing test was provided in a jar which had to be unscrewed in order to obtain the ball. The subject's hand usage for this activity was noted.

4B.14g Threading a Needle

A large needle and a piece of thread were provided. The subject was asked to pick them up and thread the needle. The hand used to provide the movement in threading the needle was noted. In general this was the hand moving the cotton to thread the needle but a few subjects held the cotton still and moved the needle towards it.

4B.14h Striking a Match

A box of matches was provided. The subject was asked to pick up the box, open it and strike a match. The hand used to strike the match was noted.

4B.14i Dealing Cards

A standard pack of playing cards was provided. The subject was asked to pick up the pack and deal off a few cards. The hand that removed the cards from the pack was noted.

4B.14j Kaleidoscope

An ordinary child's kaleidoscope (Chad Valley brand) was provided. The subject was asked to pick up the toy and look through it. The eye used was noted.

4B.14k Sighting Through Tube

A cardboard tube 12" in length and $1\frac{1}{4}$" in diameter was held in a laboratory clamp stand. A small (2" x 2") cross was drawn on the wall at the approximate level and about three feet from the tube. The subject was asked to move the tube laterally so that the cross could be seen through the tube. Before the subject began this test the tube was moved so that the cross could not be seen. The eye used for looking down the tube was noted.

4B.14l Sighting Rifle

A large toy rifle was provided. The subject was asked to aim the rifle at a point outside the window, and the eye used for sighting was noted. It was not noted that the female twins were at any apparent disadvantage in this test, though this might have been expected. All appeared familiar with the basic aiming procedure.

4B.14m Listening to a Clock

The subject was asked to listen closely to an automatic timer of clock-like appearance and to tell the interviewer whether it was ticking. The subject was not allowed to touch or pick up the 'clock'. In fact it was not ticking. The ear used for this activity was noted.

4B.14n Kicking a Ball

A small ball was provided and the subject was asked to kick it to hit the door. The foot used was noted.

4B.14o Hopping

The subject was asked to hop on one foot for three paces. The foot used in hopping was noted.

4B.14p Stamping

The subject was asked to imagine that a spark had fallen from a fire onto a mat, and then to stamp out this imaginary spark. The foot used to stamp was noted.

4B.14q Hair Whorl and Thumb Size

The subjects' scalps were examined and the position of their hair-whorls were noted. In the smaller children this could be done while they were standing but the larger ones were asked to be seated.

The thumbs of each individual were compared and any differences in thumbnail size were noted.

4B.14r Grip Strength

Grip strength was measured by means of a Stoelting Co. dynamometer. (see Section for a discussion of the dynamometer's reliability). This records grip in terms of pounds. Unfortunately as this instrument was borrowed from another department it was not possible to obtain readings for all of the twin sample, but 44 pairs were tested. Each individual recorded five pulls on the dynamometer with each hand. The dynamometer was held in the hand with the arm extended downwards at the side of the body. No special encouragement was given to the subjects to increase their scores as this has been shown to give inaccurate results. Nor were the subjects allowed to see their scores before the test was ended.

4B.14s Tapping Speed

The subjects' record sheets included a page bearing two trellises of empty squares. Each box measured 1 cm square, and each trellis was 4 boxes by 16 boxes. The subject was asked to put a dot in as many squares as he or she could within a given time, ten seconds. The subjects were first allowed to practise on a spare sheet of paper in order to establish that they understood what was required. They were advised to start at the top left corner with the right hand and proceed through the boxes changing direction at the end of each line. When using the left hand it was advised that they start at the top right hand corner of the trellis. They were also informed that dots touching the edges of the boxes would be discounted. The time was measured by means of a stop-watch. The subjects were allowed to use their hands in whatever order they preferred.

When the subject had completed the test with both hands the total number of dots produced by each hand was counted, disallowing dots touching the trellis. The dotting was done with pencil, ball point pen or fibre tip pen in order to avoid any bias that would have been caused by a conventional nib pen.

4B.15 Survey Procedure

The twins were seen individually and did not come into contact between the first and second twin being tested. The apparatus involved in the tests was laid out on a laboratory bench. The relative positions of the various pieces of apparatus were kept constant for each subject in order to eliminate any effects that different presentation of the objects might have. In fact the position of each item was marked on the bench.

A standard record sheet was duplicated and the tasks were performed in the same order in each case. Unfortunately the remainder of the laboratory which was not being used in the survey was sometimes occupied by other research projects. This may have been a distracting influence on the subjects, however the majority of the tests required little concentration. In all the tests it was hoped to determine the usual laterality reaction rather than a planned reaction by the subject.

4B.16 Concept of Heritability

Falconer (1961) has defined the heritability of an inherited character as the ratio of the additive genetic variance divided by the total pheontype variance. The heritability of a trait therefore is a measure of the proportion of the variation of that trait which is determined by genetic factors. This genetic variation would remain if all environmental factors were removed. If this relationship is expressed symbolically :

$$h^2 = \frac{V_G}{V_G + V_E} = \frac{V_G}{V_P}$$

where h^2 = heritability
V_G = genetic variance
V_E = environmental variance
V_P = total phenotypic variance

Heritability values vary between 0 and 1; if there were no environmental variance for a traits its heritability would be equal to one.

4B.17 Estimation of Heritability

In calculating the heritability of metric traits in animals it is usual to undertake complex breeding experiments. Such experiments can provide data on sib, half sibs, back crosses and complex relationships. The heritability can be estimated from this data with some accuracy.

When studying human populations it is found that the more complex relationships rarely occur. However the relatively high frequency of monozygotic twins makes them invaluable in this context. In monozygotic twins the genetic contribution is identical, therefore any variance between the twins must be due to environmental effects.

MZ twins are almost always reared together and therefore have environments more similar than those of unrelated persons. It would be possible to compare MZ twins reared apart with unrelated persons, but the rarity of the former group prohibits this. (Sutton 1965). But DZ twins reared together can be compared with MZ twins, provided they are of like sex.

It is assumed that the environment of DZ twins and MZ twins is similar. In fact that may not be the case, (Sutton et al 1962). It has been noted that the prenatal blood circulation may be unequally divided between MZ twins. In the post-natal situation it is often found that MZ twins are treated more similarly than DZ twins. Scarr (1968) noted that it was difficult to distinguish the parental reactions to the twins' phenotypic behaviour from the parents' expectations that the twins' behaviour would follow a certain pattern.

Though these possible drawbacks of the twin survey technique do exist it still remains the most accurate method of investigating heritability in man. The relationship between the different types of twins' variances for a particular trait may be symbolized as follows:

$$V_{DZ} = V_G + V_E$$

$$V_{MZ} = VE$$

$$V_G = V_{DZ} - V_{MZ}$$

where:

V_{DZ} = intra pair variance of the DZ sample

V_{MZ} = intra pair variance of the MZ sample.

In fact it is probable that the environmental variance of the MZ sample is less than that of the DZ sample, but it is not possible to isolate this difference.

When the distribution of twin pair differences in a metric trait is approximately normal it is possible to use the variance ratio V_{DZ}/V_{MZ} to estimate the difference between the MZ and DZ pairs. If the variance ratio, F, is significant it is probable that genetic factors have a greater influence on the phenotype variation than do environmental factors. It is also possible to calculate the value of h^2 by use of an equation devised by Newman, Freeman and Holtzinger in 1937 (1) :

$$h^2 = \frac{V_{DZ} - V_{MZ}}{V_{DZ}} \qquad (1)$$

This equation is referred to in the text as the HV (for variance) equation. The intra pair variances of MZ and DZ twins used in the HV equation are calculated from the following equation (2) :

$$V_X = \frac{1}{2N} \sum (x_A - x_B)^2 \qquad (2)$$

V_X = variance of MZ or DZ sample.
N = number of twin pairs
x_A & x_B = values of x for one twin pair.

When the distribution is not normal the above tests are not valid. (Sutton 1965). Stafford (1969) has suggested that the Mann Whitney U test should be used. This test would not give any estimate of heritability but would merely test for an association between monozygosity and similarity in the particular trait studied.

If the twin data is discontinuous it is possible to convert it to a numerical scale and then employ the V equation. This method is not wholly valid owing to the basic discontinuity of the data. It is unlikely that many discontinuous variables would fulfil the conditions required for the confident use of the V equation. However Newman, Freeman and Holtzinger (1937) derived a very simple equation which provides a crude estimate of heritability in these cases. The twin pairs are scored as concordant or discordant for the particular trait. The heritability is then calculated from the following equation (3) :

$$h^2 = \frac{\%\ \text{MZ concordant} - \%\ \text{DZ concordant}}{100 - \%\ \text{DZ concordant}} \qquad (3)$$

This equation is referred to as the HC (for concordance) equation in the text. The main disadvantage of this statistic is that when all the MZ pairs are concordant the value of h^2 is always 1.0, this value being unchanged by different degrees of concordance in the DZ sample. It is accepted that this statistic is most unsatisfactory, but as the twin survey was designed as a minor part of the main project it was not possible to allow time to develop an alternative procedure.

Both Shields (1962) and Sutton (1965) suggest that a chisquare test can be used on twin data, though Stafford (1969) prefers the 'U' test. As in the 'F' test this does not provide a value for heritability but shows any association between concordance and monozygosity. It is possible to calculate the coefficient of contingency from the chisquare result.

$$Co = \sqrt{\frac{X^2}{X^2 + N}}$$

Co = coefficient of contingency

X^2 = Chisquare value

N = grand total

This coefficient provides a measure of the association of concordance and zygosity, but it must be accepted that the maximum coefficient that can be obtained in a 2 x 2 table is 0.707. Values of the contingency coefficient should be interpreted in relation to this maximum rather than unity (Siegal 1956). The significance of the contingency coefficient is taken as being equal to that of the chisquare value from which it is derived.

4C - Twin Survey Results

4C.1 Composition of Twin Sample

Blood typing was carried out on 52 of the 58 pairs included in the sample. Of these 28 pairs were concordant in all their blood groups and were diagnosed as probably monozygotic. The remaining 24 pairs differed in one or more blood groups and were classified as definitely dizygotic. One pair who were visibly almost indistinguishable differed in the strength of the reaction in the P blood system. The Blood Group Reference Laboratory stated that the amount of variation was within the bounds of experimental error and so the pair were accepted as monozygotic. (see table 04)

The remaining six pairs were all apparently dizygotic. It was decided to use the method of Slater (1963) to attempt to diagnose their zygosity from the fingerprints collected in the survey. The discriminant function Z was calculated (see Methods 4B.10) and the results were compared with the tabulated probabilities of dizygosity in Slater's paper. In one case the probability of the pair being dizygotic was greater than 0.96, a very satisfactory result. Two pairs had probabilities greater than 0.68 but less than 0.76 and one pair had a probability greater than 0.59 but less than 0.68. In the remaining two cases the probability of the pairs being dizygotic was found to be low. In one pair p was between 0.41 and 0.33 and in the other pair it was between 0.32 and 0.25. (see table 05)

It was hoped to avoid classifying the twins' zygosities by anthroposcopic methods, as it was felt that this would bring a circularity into the calculation of the heritabilities of the individual traits such as hair colour. However in the case of these two pairs of twins the facial differences were very marked, and both pairs were found to differ in the majority of the survey traits. It was therefore decided to include both these pairs in the dizygotic group. This gave a total sample of 28 MZ pairs and 30 DZ pairs, the other four pairs with no blood grouping being accepted on the finger-print result.

The sex distribution of the two twin groups differed. Of the MZ pairs only 8 were males and 20 were females. In the DZ group the sexes were approximately equally represented as 14 pairs were male and 16 pairs female. The DZ group as a whole were slightly older than the MZ group. The mean age of the dizygotic twins was 13.8 years as compared with 13.4 years in the monozygotic group. In view of the small size of the MZ male group it was decided not to divide the groups into single sex classes, but it was noted that the MZ males were on average older than the MZ girls and the DZ girls were older than the DZ boys. (see table 06)

4C.2 Twin Survey Results ; Non Laterality Variables

4C.2a Heritability of Eye Colour

There were slight eye colour differences in three of the 28 MZ pairs (10.7%). This difference only represented slight variations in pigment distribution between the twin pairs. The pairs with differences were classified as follows: grey and blue-grey; blue-grey and grey green, and hazel and green-brown. When the eye colours were combined to give light, mixed and dark groups it was found that the discordant MZ twins were either one light-eyed and one mixed or one mixed and one dark.

In the DZ twins there were eye colour differences in 18 pairs (60%). In 11 of the pairs the differences were slight as in the MZ pairs. The remaining 7 pairs (23.3%) showed marked differences, that is the twins were classified as one light-eyed and one dark eyed when the combined colour groups were formed.

From the HC equation these figures give a heritability of 0.82% for eye colour. A 2x2 chisquare test comparing concordance or discordance in the two groups shows a significant association is present. A contingency coefficient of 0.46 was found.

If the data is scored as a numerical variable with light eyes scoring one, mixed eye colour two and dark three, a further estimate of h^2 can be obtained from the HV equation. In this calculation a heritability of 0.85 is found. (see tables 07a, 08)

4C.2b Heritability of Colour Vision

Only the male twins were tested for this trait. One DZ pair were found to be concordant both for the presence of colour defect and for the degree and type of defect. Both were assessed as having medium grade deutan defects. Their mother who accompanied them had normal colour vision. (see table 09)

4C.2c Heritability of Hair Colour

When hair darkness and hair redness were measured by using a standard range of hair colours it was found that all the MZ pairs were concordant for both characteristics. In the DZ twin pairs 60% were discordant for hair darkness and 23.3% for hair redness. In such a case where all MZ pairs are concordant the HC equation gives a value of 1.0 for heritability. When a 2x2 chisquare test was carried out the association of concordance and monozygosity was highly significant and a contingency coefficient of 0.44 was found. This test was only applied to the data on hair darkness as there were insufficient discordant pairs to perform the test for hair redness.

If the hair darkness data is transformed to a scale with light hair scoring 1 and the darkest hair scoring 4 the data can be used with the HV equation. However in this case h^2 is still 1.00.

When the hair samples from the twins were later examined and classified by the Munsell method the resulting data was used with the equation. A heritability value of 0.86 was found for chroma (colour intensity), and value (hair darkness) was found to have a heritability of 0.93. In fact only 4 (14.3%) of the MZ twin pairs showed any differences in chroma, and these differences were only splitting the pair into adjacent classes. But in the DZ twins 13 (43.3%) showed differences and many of these were two or more classes apart. Value (or hair darkness) was only found to differ in one MZ pair (3.6%) but 50% of the DZ pairs had value differences. (see tables 07a, 010)

4C.2d Heritability of Ocular Defects

Two of the MZ pairs (7.1%) were discordant in their need to wear corrective glasses. In the DZ pairs 11 (36.7%) were discordant for this characteristic. These results gave a heritability value of 0.81 for the HC equation. A 2x2 chisquare test gives a significant result and the contingency coefficient is 0.34.

If the data is scored counting 1 for glasses not needed, 2 for part-time wear and 3 for full time wear, the HV equation gives a value of 0.50 for h^2. (see tables 07a,011)

4C.2e Heritability of Hair Form

All the MZ pairs were concordant for hair form, but 53.3% of the DZ pairs were discordant. The 100% concordance of the MZ sample meant that h^2 was found to be 1.0 both using the HC equation and transforming the data to scores and using the HV equation. The coefficient of contingency was 0.51 and the 2x2 chisquare test gave a highly significant result. (see tables 07a, 012)

4C.2f Heritability of Hair Line

This trait showed more variation in the MZ sample. Discordance was noted in 8 (25.6%) of the MZ pairs though in all cases the twins were divided between absent and intermediate classes or intermediate and present. In the DZ sample 14 (46.7%) were discordant, and 4 of these pairs had one member with a definite peak and one without. Using the HC equation h^2 is only 0.39. A 2x2 chisquare comparison does not show any significant association between concordance and monozygosity in this trait, and the contingency coefficient is only 0.18.

However, if the characteristic is scored with 1 for no peak, 2 for intermediate peak and 3 for definite peak, the HV equation gives a h^2 value of 9.67. (see tables 07a, 013)

4C.2g Heritability of Ear Lobe Type

There were slight differences in three MZ pairs (10.7%), these being classified as one free and one intermediate, one intermediate and one attached, or one attached and one fixed. In the DZ sample 60% had some difference of ear lobe type. Using the HC equation, h^2 is found to be 0.82. The contingency coefficient for this association was 0.46 and a 2x2 chisquare test gave a very significant value. (see tables 07a, 014)

4C.2h Heritability of Chin Type

If concordance is defined as having the same type of chin indentation, 4 (14.2%) MZ pairs and 16 (53.3%) DZ pairs are discordant. However if concordance is only related to the presence or absence of a chin indentation only 3 (10.7%) of the MZ pairs and 15 (50%) of DZ pairs are discordant. In the first case a value of 0.73 for h^2 is obtained using the HC equation and h^2 is 0.79 for the second classification. The contingency coefficient is 0.38 and the 2x2 chisquare is significant.

When the data is transformed to a three part scale, no cleft counting 1, slight cleft 2 and deep cleft or dimple 3, the HV equation gives a value of 0.70 for h^2. (tables 07a,015)

4C.2i Heritability of Fingerlength

There were 10 (35.7%) discordant MZ pairs and 19 (63.3%) discordant DZ pairs. These results give a value of 0.44 for h^2 using the HC equation. The contingency coefficient is 0.27 and the chisquare test is significant though only at the 0.05 level.

If the results are scored on a 1 to 3 scale with one point for long index finger, two for equal index and ring and three for a long ring finger, the HV equation gives h^2 equal to 0.40. In this case the variance value is only just significant being almost exactly the tabulated value of F for $p=0.05$. (see tables 07a, 016)

4C.2j Heritability of Freckles

Only one MZ pair differed in freckling, one twin having no visible freckles and the other having a few. In the DZ twins 16 (63.3%) of the pairs differed in this characteristic, and in two of these cases one twin had no freckles while the other was heavily freckled. The heritability was found to be 0.93 using the HC equation. A 2x2 chisquare test showed a significant association between concordance and zygosity and the contingency coefficient was 0.50.

If the data was scored allowing one point for no freckles, two for light freckling and three for heavy freckling, the heritability value was found to be 0.95 using the HV equation. (see tables 07a,017)

4C.2k Heritability of Mid-digital Hair

In the MZ sample there were 8 pairs (28.5%) who differed in the number of fingers showing mid-digital hair. If the classification was changed so as to include only presence or absence of MDH, only 4 of the MZ twins were discordant. Similarly 13 (43.3%) of the DZ twins were discordant when all the fingers were considered but only 5 (16.7%) if presence or absence of MDH was the classification factor.

For the total finger comparison h^2 was found to be 0.34 using the HC equation. The coefficient of contingency was only 0.15, and the result of the 2x2 chisquare test was not significant. If the heritability of the presence or absence of MDH is calculated a value of only 0.15 is found.

Rather higher values of h^2 are found when the results are scored according to the number of fingers with hair. This gives a 0 to 4 scale. Using this scale h^2 is found to be 0.46 when the HV equation is employed. (see tables 07a,018)

4C.21 Heritability of the Secretor Trait

It was intended that the secretor trait should be included in the twin survey. Though the heritability of this trait is established as being on a par with that of the blood groups it was intended to check the experimental methods used in the main survey by means of the twin survey. Saliva samples were collected from all the twins and prepared and then stored in a deep freeze until the twin survey ended.

However when the samples were sought for testing it was found that an unknown person had removed them from the deep freeze and had left them at room temperature. Since it was established that the samples had been left defrosted at room temperature for at least three days it was felt that they would be too decayed to be used with any success, and the test therefore was abandoned.

4C.2m Heritability of Phenylthiocarbamide Tasting

The data for PTC tasting can be interpreted in various ways which will produce differing heritability values. If the twins are divided into tasters and non-tasters at the general antimode 3/4 which was found to apply to the main survey, then 2 (7.1%) of the MZ and 3 (10.0%) of the DZ pairs are discordant. This gives an h^2 value of 0.29 using the HC equation.

If concordance of tasting threshold is used to classify the twins it is found that only 3 MZ pairs are concordant in tasting the same solution as compared to 6 of the DZ pairs. This gives a nonsense result for the heritability of -0.12. When the taste threshold is widened so that the twins tasting the same concentration $\pm$ one dilution, h^2 is 0.21. If the classification takes $\pm$ 2 dilutions as concordant $h^2 = 0.42$, $\pm$ 3 dilutions $h^2 = 0.46$ and $\pm$ 4 dilutions gives a h^2 value of 0.57. However this test value accepts as concordant twins one of whose taste threshold is 32 times stronger than the other, which does not seem to be a reasonable level of variation.

If the HV test is employed using the solution numbers

0 to 13 as scores, h^2 is found to be 0.62. However, it is uncertain whether it is appropriate to use this method on bimodal data. In view of this it was decided to exclude the non-taster pairs who formed the smaller part of the distribution, and also those pairs where one member was a taster and one a non-taster. This left the major part of the twin data, all those pairs where both twins' taste thresholds were within the range from dilution No 4 to dilution No 13. In all, six pairs of twins were discarded from each group. The remaining data when used with the H2 test gave a heritability value of only 0.08 and in this case the variance ratio was not significant. (see tables 07a, 020)

4C.2n Heritability of Height, Weight, Ponderal Index, Foot Length and Foot Width

In the case of the metric variables it was only appropriate to carry out the HV test. The sample size was not sufficient to allow separate heritability estimates to be given for the sexes, and so the values for the whole sample are given. The heritability of height was found to be 0.91 and weight had a heritability value of 0.92. The heritability value of ponderal index was 0.87 and the heritability of foot length was found to be 0.89. In all these cases the intra pair F values were significant and the inter group F values were not significant in height, weight and foot length. In the ponderal index comparison the inter group F value was found to be significant at the 0.01 level. The heritability of foot width was found to be only 0.07, and neither the intra pair nor the inter population F ratios were significant. (see tables 07b, 021-026)

4C.3 Twin Results Laterality Variables

4C.3a Introduction to Twin Laterality Results

Most of these variables were originally scored as right or left. There were therefore only two categories and therefore the data could not reasonably be converted into a score so that the HV test could be used.

In most of the variables the frequencies of discordant twins are very low. This is a result of the low frequency of left biased persons in the group. In view of these low frequencies it was not possible to use the chisquare test on much of the laterality data.

4C.3b Heritability of Hand Usage in Writing

Three (10.7%) of the MZ twins and 6 (10.0%) of the DZ twins differed in the hand they used for writing. This gave a heritability of 0.47 by the HC test. (see tables 07c,027)

4C.3c Heritability of Hand Usage in Throwing a Ball

Only 2 (7.1%) of the MZ pairs threw a ball with opposite hands as compared with 4 (13.4%) of the DZ twins. This result produced a h^2 value of 0.48. (see tables 07c, 028)

4C.3d Heritability of Hand Usage in Unscrewing a Jar Top

This activity produced more variation. In the MZ group

10 (35.6%) differed in the hand used, and in the DZ group 13 (43.4%) were discordant. The heritability of hand usage in this ability was therefore found to be 0.18. (see tables 07c, 029)

4C.3e Heritability of Hand Usage in Cutting with Scissors

In the MZ pairs, 3 (10.7%) were discordant, as were 4 (13.4%) of the DZ group. The heritability value for this factor was 0.20. (see tables 07c, 030)

4C.3f Heritability of Hand Usage in Dealing Cards

Three (10.7%) MZ pairs differed in the hands they used to deal cards as compared with 10 (33.3%) of the DZ pairs. This difference gave a heritability value of 0.68 for this characteristic. (see tables 07c,031)

4C.3g Heritability of Hand Usage in Hammering a Nail

Only 2 (7.1%) of the MZ pairs with discordant but 6 (20.0%) of the DZ twins differed. These results gave an h^2 value of 0.65. (see tables 07c,031)

4C.3h Heritability of Hand Usage in Threading a Needle

In the MZ sample 6 (21.6%) of the pairs were discordant, as were 10 (33.3%) of the DZ pairs. The heritability value of this factor was found to be 0.35. (see tables 07c, 33)

4C.3i Heritability of Hand Usage in Striking a Match

Two of the MZ pairs (7.1%) used opposite hands when striking a match but this difference was present in 5 (16.6%) of the DZ pairs. In this case the heritability was 0.58. (see tables 07c,34)

4C.3j Heritability of Hand Usage in Reaching Up for an Object

Of the MZ twin pairs 5 (17.8%) used different hands for this activity whereas only 4 (13.4%) of the DZ twins did so. This meant that a nonsense value of h^2 equalling -0.31 was created. (see tables 07c,35)

4C.3k Heritability of Eye Usage in Viewing a Kaleidoscope

When looking down a kaleidoscope 13 (46.4%) of the MZ twin pairs used opposite eyes and in the DZ sample 19 (63.3%) differed in their eye usage. The heritability value for this trait was 0.27. (see tables 07c, 36)

4C.3l Heritability of Eye Usage in Sighting a Rifle

In this comparison 9 (32.0%) of the MZ twins and 14 (46.4%) of the DZ twins were discordant. The value of h^2 was found to be 0.31. (see tables 07c, 37)

4C.3m Heritability of Eye Usage in Sighting Down a Tube

The MZ twin group contained 12 (42.8%) pairs who differed in their eye usage in this activity, but 16 (53.4%) of the DZ pairs did so. The heritability of this eye usage was calculated to be 0.20. (see tables 07c, 38)

4C.3n Heritability of Foot Usage in Kicking a Ball

Only 1 (3.5%) MZ pair and 2 (6.6%) DZ pairs differed in this activity. The heritability was found to be 0.47. (see tables 07c, 39)

4C.3o Heritability of Foot Usage in Stamping Out Spark

There was more variability in this activity. In the MZ pairs 7 (25%) used opposite feet to stamp out sparks, and 11 (36.7%) of the DZ twins did so. This gave h^2 equal to 0.32. (see tables 07c, 40)

4C.3p Heritability of Foot Usage in Hopping

The heritability of foot usage in hopping was found to be 0.51. Ten (35.8%) of the MZ pairs and 22 (73.4%) of the DZ pairs differed in this activity. (see tables 07c, 41)

4C.3q Heritability of Ear Usage in Listening to a Watch

It was found that 6 (21.6%) of the MZ pairs used opposite ears as did 7 (23.3%) of the DZ pairs. This gave a heritability value of only 0.07 for this activity. (see tables 07c, 42)

4C.3r Heritability of Hair Whorl Position

In the MZ twins 2 (7.1%) of the pairs had differing positions of their hair whorls. In the DZ group the number was 4 (13.4%). The heritability value for this was 0.48. (see tables 07c, 43)

4C.3s Heritability of Thumb Size

The MZ twin group contained 3 pairs who differed in the laterality of their larger thumbs. In the DZ group 11 (36.6%) were different in this respect. The heritability value for this trait was found to be 0.71. (see tables 07c, 44)

4C.3t Dynamometer Test Results

Five Dynamometer readings were available for each hand of each twin of 44 of the twin pairs. It was decided to calculate by means of the 't' test how many individuals in the twin pairs had significant differences between their right and left dynamometer readings. It was also decided to compare the right and left hands of the twins to estimate whether the corresponding hands of MZ pairs were more similar than those of DZ pairs.

In the total twin group taken as individuals 56.8% had significant differences between the strengths of their right and left hands. In the MZ twin group 67.1% had significant differences, but only 45.2% of the DZ twins showed this difference.

When the data is examined in terms of twin pairs it can be seen that 69.6% of the MZ pairs are concordant either having both twins without significant differences in grip strength or both with significant differences. Only 47.6% of the DZ group show this concordance, thus giving an h^2 value of 0.42 for the heritability of handgrip difference.

Comparing the grip strength of the right hands of the twin pairs it was found that 43.5% of the MZ pairs showed significant intrapair differences as compared to 52.4% of the DZ pairs. The difference in the left hand comparison is more notable. In the MZ sample only 26.1% of the pairs had significant differences between their left hands, but 75.2% of the DZ twins showed this difference.

The heritabilities of the grip strength of the right, left and combined hands were calculated. The mean dynamometer readings were used for the right and left calculations, and the mean of all the right and left readings was used in the combined hand strength calculation. The heritability of right hand strength was found to be 0.91 and left hand strength was 0.86. The combined hand strength value had a heritability of 0.90. In terms of strict definition these values were not right and left hand with dominant and non-dominant hand. The results were arranged so that those who had a dominant left hand were counted among the right handed for calculation purposes. This was to avoid any diminution of the final heritability values, where twins differed in their handedness. (see tables 07c, 45 - 49)

4C.3u Tapping Test Heritabilities

The number of "taps" recorded in ten seconds by each hand of each twin was noted. It was therefore possible to calculate three heritabilities, that is the heritability of right hand tapping speed, left hand tapping speed and a combined hand tapping speed. It was found that the combined hand tapping speed, which was calculated as the mean of the speeds of the right and left hands, had a heritability of 0.46. The heritability of left hand tapping was found to be 0.63, however the heritability of right hand tapping speed was only 0.07. In the combined tapping speed and the left hand tapping speed the intra pair F ratios were significant, but the F ratio for right hand tapping was not significant. (see tables 07c, 50-52)

4D - Twin Survey Discussion

4D.1 Zygosity of Twin Sample

When the possibility of using the 'Frost Programme' twins was under consideration it was decided to contact the other organisations using the twin sample. It was proposed that any zygosity data concerning the twins should be pooled, the interested parties sharing any ensuing costs. None of the other bodies were proposing to use blood typing; some used dermatoglyphics, some a side-by-side comparison and some relied on a postal questionnaire.

In view of this experience, combined with the opinion of Slater (1964) that some DZ twins have dermatoglyphics as similar as MZ twins, it was thought legitimate to include in the DZ sample the two unchecked pairs. No blood samples were available for these pairs and their dermatoglyphic comparisons did not exclude the possibility of their being monozygotic. However Shields (1962) was prepared to include in his sample twin pairs who had not been blood typed. In fact both the twin pairs in question were considered to be definitely dizygotic by both the workers concerned with the twin survey. (see 4C.1)

4D.2 Heritability of Eye Colour

It was noted by Nichols and Bilbro (1966) that 5% of MZ twins showed slight differences in eye colour. However Rife (1938) thought eye colour a good indicator of zygosity and both Sammalisto (1961) and Ardashnikov (1936) used this trait in deciding twins' zygosity. Sutton et al (1962) excluded from their MZ groups three pairs who were concordant in all blood groups but discordant in eye colour. Shields (1962) notes that there is a large amount of experimental error in classification of eye colour. In view of these factors it is to be expected that high heritability values for eye colour would be obtained, and it might be felt that the values of $h^2 = 0.85$ were rather low. (see 4C.2a)

4D.3 Heritability of Colour Vision Defects

The low frequency of colour vision defects in the population combined with the small sample size meant that only one pair with colour vision defects were found. This pair were in fact dizygotic. However Shields (1962) note two MZ pairs who were concordant in their colour vision defect. (4C.2b)

4D.4 Heritability of Hair Colour

Shields (1962) notes that hair colour in MZ twins may vary even when the effects of sunlight are allowed for. Nichols and Bilbro (1966) found that 13% of their MZ twins differed slightly in hair colour or hair texture, though they included this trait in their zygosity questionnaire. Hair colour was also used by Sammalisto (1961) in his study of Finnish twins. The results of the present survey would seem to indicate a greater similarity between MZ twins than that found in the surveys of Shields and Nichols and Bilbro. No differences between MZ twins were present when their hair was classified on a crude scale. When the hair colour was analysed in terms of chroma and value on the Munsell Scale it appeared that the intensity of colour varied more than the actual darkness of the hair, though both had very high heritabilities. It is possible that the heritability of Munsell value (hair darkness) represents the heritability of melanin pigment present in the hair, while the result for chroma represents the heritability of intensity of another pigment. This could be the yellow-red pigment proposed by Hanna (1956). (see 4C.2c)

4D.5 Heritability of Ocular Defects

Sorsby (1964) noted that 23 out of 78 MZ twin pairs were discordant in their ocular refraction. He suggests that the inheritance of ocular refraction may be the result of a number of genes with additive effects and no dominance. Sorsby (1970) also states that myopia can be influenced by prematurity and Francois (1961) quotes instances of discordance in MZ twins for a number of ocular defects. In view of the crudity of the classification of ocular defects in the present survey the h^2 value of 0.81 is somewhat unexpected. (see 4C.2d)

4D.6 Heritability of Hair Form

Both Shields (1962) and Nichols and Bilbro (1966) have found that the texture of the hair of MZ twins may differ. It is uncertain what is meant by texture, but in the present survey the hair form was found to be identical in all the MZ twins. In view of the high heritability of hair colour it might be expected that hair form would also have a high heritability value. In fact the small sample size and the limitations of the heritability calculations give rise to a heritability value of 1.0 which is probably somewhat exaggerated. (see 4C.2e)

4D.6 Heritability of Hair Line

No previous data on the inheritance of hair line type was available. The lack of any significant association between concordance for this trait and monozygosity might seem to indicate that heredity plays only a minor part in its determination. However it was noted that when the trait was scored as a metric trait the heritability was found to be 0.67. (see 4C.2f)

4D.8 Heritability of Ear Lobe Type

Nichols and Bilbro (1966) suggested the use of ear lobe type in classifying twins' zygosity, and Shields (1962) studied the ears of his twin pairs. It is probable that the slight variations noted within MZ pairs is developmental variation. It may be that ear lobe type should be measured as a continuum and that the arbitrary division leads to apparent differences where there is only slight variation. The final result for ear type was a heritability of 0.82. (see 4C.2g)

4D.9 Heritability of Chin Type

The heritability of this trait has previously been examined by Krogman (1967) who noted 100% penetrance in a twin survey. A certain amount of variation in the manifestation of the trait was noted in the present survey, but the heritability was found to be high. It is probable that the variation in apparent chin type in MZ twins is due to complex factors including fat deposition and facial musculature. (see 4C.2h)

4D.10 Heritability of Fingerlength

Although there was a significant association between concordance and monozygosity this was only at a low level and the overall heritability of finger length was low. This trait is in a state of change during adolescence (Rosler 1957), and so it is possible that this factor could affect the present survey results. However it has been noted elsewhere in this survey that there appears to be a high degree of concordance for growth spurt in MZ twins. In this case it seems unlikely that growth effects should give rise to excess discordance in finger length of adolescent MZ twins. It may be that this characteristic owes a large part of its development to environmental factors. (see 4C.2i)

4D.11 Heritability of Skin Type

Auerbach (1962) has noted that differences in exposure to sunlight can produce variation in skin type in MZ twin pairs, such differences have also been noted by Newman (1928a). Only one pair of MZ group showed any difference large enough to result in the twins being placed in different classes. It is probable that the subjects being schoolchildren meant that their periods of time spent on indoor activities were controlled and no situation of extreme difference in this respect could arise. In adults it would be possible for one twin to be an outdoor worker while the other remained indoors. Thus it is possible that the very high value of 0.93 for the heritability of skin type may in fact be inflated by the nature of the survey subjects. (see 4C.2j)

4D.12 Heritability of Mid-digital Hair

The heritability values for mid-digital hair was unexpectedly low, being only 0.34 if the presence or absence of MDH is noted and only 0.15 if the various finger hair patterns are taken into account. As previously stated, finger hair is thought to be determined by a multi-allelic series and family studies in general fit this hypothesis. However there is a possibility that the MDH in females is rudimentary, (Danforth 1921) and Saldanha and Guinsberg (1961) have shown that there is an increase in MDH in males at puberty. It is possible that the ages of the subjects in the present survey have meant that some MZ pairs showed differences due to the effect of puberty on MDH that will not be present in adulthood. It may be that the basic variable only determines the presence or absence of MDH and that the variation in finger hair pattern are due to chance alone. If this were the case it would not be expected that the finger hair patterns would appear to be oriented around the fourth digit, but rather that finger hair was distributed at random. It was noted that Nichols and Bilbro (1966) suggested that mid-digital hair type could be used in a zygosity questionnaire. (see 4C.2k)

4D.13 Heritability of the ABO Secretor Trait

As previously stated it was not possible to obtain an estimate of the heritability of the secretor trait. Since the ABO secretor trait is generally accepted as having a heritability comparable to that of the blood group system this estimation could only have represented a check upon the methods employed in the survey. (see 4C.21)

4D.14 Heritability of Phenylthiocarbamide Taste Threshold

Phenylthiocarbamide tasting is one of the most commonly investigated traits in population genetics. The data on the heritability of this trait is scarce and somewhat confused. Ardashnikov et al (1936) found that 3 MZ pairs out of a total of 137 differed in the ability to taste PTC. Of these one pair might possibly be discounted because one member was pathologically handicapped, but the other two pairs were normal. Rife (1938) noted that 3 out of 31 MZ pairs differed in their PTC reaction and concluded that this trait was of doubtful validity in zygosity diagnosis. Dencker et al (1959) found that 2 MZ pairs in a sample of 28 were discordant in PTC tasting. These discordant pairs were re-tested, and it was found that they varied from concordance to discordance. Dencker and his fellow workers suggest that PTC tasting may be modified by exogenous factors which have a periodic effect. They quote the work of Weber who used a series of concentrations of PTC and found that, of a total of 70 MZ pairs, 15 differed by one solution and 5 by two or more steps. One of Dencker's two discordant pairs differed by 8 solutions on the Harris and Kalmus scale at one testing, but had previously been concordant. Verkade et al (1959) used a derivative of PTC, paraethoxy-PTC which has the same taste properties. In their group of 70 MZ twin pairs, two pairs showed consistent differences over a period of six months. Only one solution was used, and the same twin was always a taster while the other remained a non-taster.

In the work of Shields (1962) 74 pairs of MZ twins were tested with four solutions of the Harris and Kalmus range. It was noted that 6 pairs differed in the solution tasted and a further 16 showed slight differences in their taste reactions. Another study comparing the heritability of taste threshold was carried out by Sutton et al (1962). These workers used a serial dilution series similar to the Harris and Kalmus range, and found that 6 of their 44 MZ pairs differed in comparison with 11 of their 37 DZ pairs. If the trait was simply scored as concordant or discordant there was no significant difference between the twin types. However, if the data was treated as a metric variable the difference was significant.

In contrast to these results, Kaplan et al (1963) found that all of their group of 46 MZ twin pairs were concordant, not only for the basic taster ability but for the same taste threshold within a serial dilution. They exclude the results from one pair because one member was undergoing hormone therapy. These workers also note that taste thresholds may be affected by the subject's self-medication with aspirin or if female by the stage of the menstrual cycle. These differences disappeared on retesting. It is perhaps significant that Kaplan and his co-workers do not use PTC but prefer to use 6-propyl-thiouracil, but it is unlikely that this compound would differ from PTC in this particular respect.

In view of the above data it is not unexpected that the results of the PTC tasting in the present survey gave low estimates of heritability. It is possible that the preponderance of females in the MZ twin sample could have exaggerated any MZ twin differences if the menstrual cycle is considered as a complicating factor. Beiguelman (1964c) found no effect of the menstrual cycle on PTC tasting, but Glanville and Kaplan 1965 ab) reported that many subjects showed a lowered taste threshold for PTC during the menstrual period. In one case the change in sensitivity was 1024fold. It has been noted previously that menstruation is a complicating factor in the perception of odours (Le Magnen 1949, Elsberg et al 1935), so it is not unreasonable that this factor should also affect taste sensitivity.

It has also been noted that retesting of the same individuals reveals changes in their PTC sensitivity. (Hoover 1956, Soltan and Bracken 1958, Guttman et al 1965, Skude 1960). Since the subjects in these groups were of both sexes it must be assumed that there is an unknown degree of variation in the taste threshold of any individual.

If this variation is in fact present it is unlikely that it would be of any importance in population studies. It would be likely that the taste threshold of the members of the population would be varying independantly and in random directions. However in the case of twin studies it would seem that it is necessary to test both the twins on a number of occasions in order to assess the full range of variation of their taste thresholds. It is possible that those twins scored as concordant in this survey and the previous surveys cited might have proved discordant if retested at a later date. Although some workers have carried out repeated tests on the same subjects (Glanville and Kaplan 1965ab) there are only scattered reports on re-tested twins. In the present work it was considered whether the twin pairs should be tested again but in view of the uncertainty as to the toxicity of PTC (see section 5D.15) it was decided that this would be inadvisable. (see 4C.2m)

4D.15 Heritability of Metric Variables

In the present survey the heritability of height was found to be 0.91. This value may be compared with those calculated from the data of Osborne and de George (1959). In these workers' report the male and female twin samples are separate. It is found that the h^2 value for height is 0.79 in males and 0.92 in females. Shields (1962) notes a heritability of 0.89 for height in females, and also quotes Newman et al who found a heritability of 0.88 in a sample of twins aged from 12 - 20 years.

The heritability of weight as measured in the present survey was 0.92. This value is much higher than those reported by Osborne and de George who found a heritability of 0.42 for females, but only 0.05 for males. In both groups there was no significant difference between variables in the MZ and DZ twin pairs. Shields (1962) noted that the heritability of weight in females was 0.57 and quotes the investigation of Newman et al when the heritability of weight was found to be 0.78. In Clark's study the heritability of weight was found to be 0.71.

Ponderal Index was found to have a heritability value of 0.87 in the present survey. If the appropriate calculations are carried out using the data of Osborne and de George it is found that in their samples the heritability of ponderal index was 0.33 in males and 0.55 in females, while Clark found a heritability of 0.71. There was a significant difference between the twin types in the female group but not among the males.

From Osborne and de George's sample it was found that the heritability of foot length was 0.84 in males and 0.82 in females, and Clerk quotes a value of 0.81. These results are in good agreement with the findings of the present survey, where the heritability of this trait was calculated to be 0.89. Foot width was found to show great intra-pair variation in both MZ and DZ twins. The two groups did not differ significantly in their foot width variation, and the heritability of foot width was only 0.07. This result is partially confirmed by the data of Osborne and de George. From their results it is found that the heritability of foot width is 0.51 in males and only 0.08 in females. Neither of these groups showed any significant difference between the MZ and DZ classes for this trait.

With the exception of foot width heritabilities of the metric variables calculated in this survey are rather higher than the previously quoted data. It is possible that this is an effect of the heritability of the maximum growth period of adolescence. If height weight and foot length were all determined by a common inherited factor it would be expected a sample of DZ twins including various stages of adolescence would show greater variability than an adult sample. A DZ twin pair could differ in their growth patterns and yet achieve similar final measurements, whereas an MZ pair would be expected to be more similar at all stages of their growth. Figure 9 shows the most dissimilar pairs of MZ and DZ twins with regard to height.

It has been suggested by Vandenberg et al (1962) that there may be greater intra pair variation in female MZ twins in anthropometric variables. The hypothetical cause of this variation is the random inactivation of the X chromosome under the Lyon hypothesis. If anthropometric and other traits are influenced by factors on the X chromosome female MZ twins' heterozygosity for these factors could display phenotypic differences according to the relative proportions of the two Xs inactivated. Other workers have suggested that when one X chromosome is defective this may be selectively inactivated, or rather that cell lines bearing only the

Fig. 9. Twin pairs most different in height

a. Monozygotic

b. Dizygotic

defective X in an active state are less viable. (Gartler and Sparkes 1963, Rohde and Berman 1963). This phenomenon would give rise to greater similarity in those female MZ pairs with a defective X chromosome, but it is unlikely that such pairs occur in a frequency large enough to influence general twin population results. (see 4C.2n)

4D.16 Heritability of Laterality

The basic problem in determining the heritability of components of laterality is that the effect of being a member of a twin pair on laterality is not known. The possibility of situs inversus of a minor degree in MZ twin pairs can lead to circular reasoning. If an MZ twin pair showed clear evidence of situs inversus in any degree it might be reasonable to exclude them from an investigation of laterality preferences. But it has been noted that handedness differences may be a manifestation of assymetry comparable to differences in hair whorl definition and palmar patterns (Newman 1940). Newman (1930) found a correlation between reversal of hand print, handedness and hair whorl in MZ twins. Torgersen (1950) found no association between left-handedness and situs inversus and suggested that though both factors were related to twinning they were independent. Since it appears that reversal of handedness may be the only manifestation of inversion in a twin pair it is inappropriate to exclude those pairs showing other reversals. These pairs may not show differences in laterality. However it is not practicable to exclude all the MZ pairs who differ in laterality as this would lead to an inflated value of the heritability of laterality.

It has been suggested that intra-uterine factors other than inversion affect the laterality of twins. Shields (1962) quotes the work of Wilson and Jones who found that a greater percentage of twins than of single born were left handed. In Shields' own work 17% of his MZ pairs and 28% of the DZ pairs differed in handedness. He suggests the possibility that left handedness may be a form of psychological reaction in the weaker twin.

In view of the above difficulties there has been little work on twins' laterality comparisons. Newman (1930) noted the differences in palmar dermatoglyphics in twins. He noted that the palm pattern of one hand of an MZ twin resembled the equivalent hand of the other member of the twin pair more than the owner's other hand. Rife (1950) suggests that MZ twins who differ in handedness are heterozygous for the factors causing handedness and thus have the potentiality to be shifted in either direction.

Shields (1962) invited all the twins in his sample who admitted any degree of left handedness to complete a comprehensive laterality questionnaire which listed forty activities. From this they were scored as right handed, left handed or ambidextrous, taking a total score including all the activities. Shields did not investigate the heritability of each questionnaire item separately.

In the present survey it was decided that it would be wise to check the heritability of each activity's laterality preference separately. As can be seen from the results the heritability values varied from the nonsense value of -0.31 for reaching up for an object to 0.68 for dealing cards. The heritability of eye usage varied between 0.20 and 0.31, and the foot usage heritabilities ranged from 0.38 to 0.51. The single test of heritability of ear usage showed that the variation in the MZ twins was similar to that in the DZ pairs. The heritability of this trait was calculated to be only 0.07.

It seems therefore that it would be unwise to combine various laterality activity scores to give a total laterality index or a range of indices for hand, foot and eye. The heritabilities of the items included in the main survey laterality investigation ranged from 0.18 to 0.68.

The heritability of hair whorl position was noted, but in view of this trait's possible association with inversion in MZ twins the value of 0.48 may be an underestimate. In the case of the thumb nail comparisons which may be used as an indication of inversion it was found that the heritability of the laterality of the larger thumbnail was 0.71.

It was expected that the heritabilities of grip strength would be high, though Jones (1947) has noted a sex difference in grip strength this would have had no effect in the present comparison as the DZ twin pairs were all of like sex. In the case of the tapping speed it was found that the intra pair variation in dominant hand tapping speed did not differ significantly in the two twin types. The heritability of dominant hand tapping speed was found to be 0.07 in comparison to the non-dominant hand where a heritability of 0.65 was found. This difference may be explained by the effects of training for skilled tasks such as writing. Such training would only affect the dominant hand. However it is unlikely that MZ twins would be differently affected by such training. It is interesting to note that the heritability of grip strength, which is not a function of skill, is greater in the dominant hand than in the non-dominant hand.

Though it is accepted that any use of a twin survey in the study of laterality variables is limited by the possible complicating factors of inversion and the intra-uterine effects it was felt that this was a necessary step. In a further attempt to elucidate the hereditary factors concerned in laterality it would be useful to compare other methods of estimating heritability with twin survey results. (see 4C.3a-u)

4D.17 General Discussion of the Validity of Twin Surveys

Though it is assumed for the purposes of heritability calculation that the environmental effects on both types of twin pair are identical, this is probably not the case. Sutton et al (1962a) suggest that prenatal blood supply inequalities may affect MZ twins but that these differences may not be cancelled out by the similarity of post-natal treatment of the MZ twins. They suggest that any such differences will tend to decrease estimates of heritability. Scarr (1968) is of the opinion that post-natal differences will not affect physiological or anthropometric traits, though personality and cognitive traits may be influenced.

She agrees that MZ twins are treated by their parents more similarly than are DZ pairs, but also notes that the parental attitude is determined by the twins' appearance not their estimate of the twins' zygosity. MZ twins wrongly assessed as DZ by their parents were in fact treated like the majority of MZ pairs.

The lasting effect of pre-natal differences has been shown in two studies of birthweight and intelligence in MZ twins (Willerman and Churchill 1967, Kaelber and Pughl 1969). In both surveys it was noted that the twin with the lower birth weight had the lower score in intelligence tests. This relationship did not hold in DZ twin pairs (Kaelber and Pughl 1969), and it is suggested that circulatory differences in the intrauterine invironment of MZ twins might be the cause.

To be a member of a twin pair may in some way be an isolating factor. Record et al (1970) found that the verbal reasoning scores of the single born were greater than those of twins, while twins scored more than triplets. This difference is not only an effect of pre-natal conditions, as twins raised as single because of the death of their co-twin achieved scores almost equal to the single born. It is suggested that the frequent contact between twins reduces communication between them and the older sibs or parents.

The frequency of twin births is also related to environmental factors. Yerushalmy and Sheerar (1940) noted that the frequency of DZ twin births was related to the age of the mother and the birth rank. Only 0.78% of first births were twins as compared with 1.75% of the 6th pregnancies. They also noted a slight relationship between the father's age and the frequency of MZ births. Lilienfield and Pasamanick (1955) noted an increased frequency of both type of twins among the non-white population, They also noted that DZ twins were more frequent in the lower socioeconomic groups of the population. Torgersen (1951) noted regional differences in twinning in Sweden, and suggested that nutritional factors were partially responsible though multiple genetic and environmental factors also influenced the general frequency. Schreider (1969) found a positive correlation between the degree of inbreeding and the frequencies of twin births in regions of France.

It may be that any sample of twin pairs is in fact so specialized that the results from their investigation may not be applicable to the general population. However the study of twin pairs allows estimates of the heritability of inherited characteristics to be made with comparative ease. Though it would be more satisfactory to use family data to estimate heritability this is rarely possible owing to the family structure of the human species. In default of such information, twin surveys must be used, but their possible limitations must always be recognised.

4E - Twin Recognition Test

4E.1 Background to Twin Recognition Test

It was noted that Sammalisto (1961) had used passport photographs in diagnosis of the zygosity of a sample of twins, and Shields (1962) also quotes this method as acceptable. It is often difficult to obtain an accurate zygosity diagnosis if the research worker has not direct access to the twins and cannot obtain blood samples. Methods of diagnosing zygosity by questionnaire have been discussed by Nichols and Bilbro (1966) and Cederlof (1961). Since the present survey was to have access to a sample of twin pairs whose blood groups would be known it was decided to photograph them. The photographs were then to be used in a twin recognition test, which would give an estimate of the accuracy of diagnosis of zygosity from photographs.

4E.2 Method of Administration of Twin Recognition Test

The photographic films were developed and printed by the Visual Aids department of the University. The photographs used in the test measured 3" x 4". They were mounted on large sheets of display card sized 20" x 24". Each card carried six pairs of twins, with the side and front face views mounted one above the other. Each pair of photographs was occupying the approximate centre of a rectangle one sixth the area of the whole card, so that actual pairs of photographs were 4" apart horizontally and 2½" apart vertically.

The twin pairs were arranged in a sequence determined by random numbers. This was to eliminate any bias in their reference numbers which had simply been determined by the order of their appointments. A one sample runs test (Siegel 1956) was carried out to check that the distribution of MZ and DZ pairs was not biased. Although some of the MZ twins were dressed identically it was not thought that this would provide clues as to zygosity as some of the DZ twins were also identically dressed.

Questionnaires were prepared with answer boxes for 'identical' and 'non-identical' for each twin pair. In further instructions the subjects were told to decide whether each pair appeared to be identical or non-identical, and then place a tick in the appropriate answer box. Where they were unable to decide they were to leave both answer boxes blank. This was later counted as a wrong answer in the scoring. The sheets of card were arranged in sequence along laboratory benches and each subject was given a questionnaire and asked to pass down the row of cards. The major part of the testing was done during laboratory classes, but it was emphasized to the subjects that their answers should not be discussed.

A total of 84 subjects was used. Most of these were undergraduates, but a fewwere members of an evening class, members of staff and postgraduates. All the students were undergraduate and postgraduate biologists, and both they and the evening class students had previously been given a lecture on twin studies and heritability. It was therefore a very specialized sample of subjects.

4E.3 Twin Recognition Test Results

When the twin pairs were interviewed there was no doubt as to their zygosity, except in the case of one pair who were rather less similar than the MZ pairs but more similar than the DZ pairs. These were shown to be probably MZ by the blood grouping.

However in the photograph recognition test the rates of misclassification were unexpectedly high. In the monozygotic pairs the percentages of observers misclassifying a particular pair varied from 3.57% to 72.62% depending on the twin pair. The highest misclassification score was not in fact obtained by the twin pair mentioned above. In the dizygotic pairs the misclassification ranged from 3.57% to 50.0%. The mean number of observers making an error of classification was 21.9 (26.0%) in the MZ pairs and 17.1 (20.4%) in the DZ pairs. Only five of the fifty eight twin pairs were misclassified by less than 5% of the subjects.

The six pairs of twins whose blood groups were not available obtained misclassification scores ranging from 3.5% to 35.71%. All these pairs were apparently dizygotic when seen at the interview. (see table 053)

The most misclassified pairs of DZ and MZ twins are illustrated in Fig.10.

4E.4 Twin Recognition Test Discussion

The high percentage of errors in this rather crude test probably indicates the lack of experience of the observers. It is possible that the standard of the photographs might have made classification difficult, but they were judged as adequate though not of professional standard.

There does not appear to be any clear trend in the errors as a similar number of errors were made in both twin categories. Slightly more MZs were classified as DZ than the reverse. This might be expected as the result of the observers applying a too stringent interpretation of the degree of similarity required to

Fig. 10. Twin pairs most often misclassified in recognition test

a. Monozygotic

b. Dizygotic

qualify twins as identical.

It was accepted that certain pairs might be hard to classify when seen only as a photograph. However mistakes were made even with the most similar and identically dressed MZ twins and the most dissimilar DZ twins.

It is unlikely that the observers were careless in answering the survey, nor were they under any compulsion to participate if they did not wish to. All appeared to consider the problem most conscientiously.

Though Sammalisto (1961) was able to use passport photographs in a complex twin diagnosis, it seems probable that the use of photographs could lead to some disclassifications. This problem could be magnified if those classifying the photographs were not familiar with twin studies. However when the twins have actually been interviewed, photographs serve as a most useful aid to memory.

5 DISCUSSION

5A Introduction to Discussion Section

In this section the results of the survey are discussed, and relevant sections of previous work are considered. The reference numbers of the appropriate paragraphs in the results section are quoted in each section for reference.

5B - Background Data

5B.1 Geographical Background of Sample

It is perhaps unfortunate that the strength of the regional roots of the population was underestimated in the original plan. Birmingham is traditionally a city which attracts migrants from all areas, and it was expected that the proportion of migrant families in the sample would have been much higher. Though there may have been some reluctance to join the survey on the part of the Commonwealth migrants it is unlikely that those from other parts of the United Kingdom would have been similarly affected. Although it is not possible to give exact figures it can be said that the majority of the Midland sample were in fact born in Birmingham. In some cases both parents and all grandparents were born within one district of the city. (see 3B.1)

5B.2 Social Class Background of Sample

The proportions of the five social classes in the present sample are approximately the same as the proportions found in the Registrar General's last Survey (1961). There is possibly a slight bias away from the underprivileged end of the social class scale, but this would be expected owing to the nature of the survey. Only a survey such as the official Government census which is able to compel participation can obtain a truly random sample of the population. (see 3B.2)

5B.3 School Type and Sex

Although it was not possible to obtain equal size samples of the two sexes or of the two school types, it is felt that all these sub-groups are of sufficient size to be of use in the investigations. (see 3B.3)

5B.4 Associations Between Background Factors

The extremely significant association that was found between school type and social class had been expected. Burt (1961) found that the I.Q. values of children of different social class groups bore a direct relationship to the status of the parent. The whole question of ability and environmental effect is still very strongly debated. One school of thought proposes that the environment is a deciding factor in determining intellectual ability. However Burt puts the opposite view, that the poorness of the environment is the product of the lack of ability of the subject.

The association of social class and parental origin is unexpected. As previously stated the difference only occurs in females, there being an excess of SC I and II girls with English parents. This might be explained as the result of professional classes migrating to the Midlands, but in this case a corresponding increase would have been expected in the male sample. In fact the English males do have a higher proportion of SC I and II than the Midland or the British groups (23.6% as compared to 20.3% of the Midland and 15% of the British). These differences lack the magnitude of those in the female sample, where 38.5% of the English girls came from SC I or II as compared to 12.1% of the Midland and 7.8% of the British samples.

The other association found in the female sample was that between school type and parental origin. Both school type and parental origin have previously been shown to be associated with social class in the female sample. It is possible that one of these apparent associations is spurious, being produced by the association of two factors with the third. In this case the difference seems to be produced by an excess of English females in the selective schools and an excess of British females in the non selective schools. These results might be expected from the social class and parental origin comparison. As has already been stated the English females have the largest proportion of SC I and II girls, and it is also found that the British girls have the largest proportion of SC IV and V girls. This excess of SC IV and V in British is also found in the male sample.

From these associations it would seem that there is a basic association of social class and school type. The situation is then complicated by differences in social class of the migrant groups. In the present survey it appears that the English migrants tended to have a greater proportion of the professional and managerial classes than the native Midlanders, but the British migrants tended to have more semiskilled and unskilled workers. These differences are more notable when the whole sample's Midland bias is considered. (see 3B.5)

5B.5 Association of Background Factors and Other Characteristics

These are listed under the following headings :

Eye Colour	5D.1,2
Colour vision defects	5E.1-4
Ocular defects	5F.1-3
Hair Colour	5G.2-6
Hair form	5H.1
Hair line	5I.1-3
Ear lobe type	5J.1,2
Chin Type	5K.1-3
Skin type	5L.1
Mid-digital hair	5M.1,2
Finger length	5N.1,2
ABO secretor	5O.1
PTC tasting	5P.3,10
Laterality	5Q.2-6
Metric variables	5R.2-4

5C - Discussion of Pilot Survey (see 3C)

5C.1 Reasons for the Pilot Survey

The object of the pilot survey was not to provide frequency data, as the sample size was inadequate for this, but to investigate and test the methods for the main survey. In this case it is not relevant to discuss the frequencies of the various traits in the sample, though it may be noted that the uneven sex distribution is probably responsible for any unusual proportions in those traits which show sex differences.

5C.2 Modifications Owing to Pilot Survey

These modifications are discussed more fully in the appropriate sections, but a brief summary will be given here:

(1) The attempt to classify somatotypes was abandoned as a result of the pilot survey experience.

(2) It was found difficult to measure height accurately using an anthropometer without assistance.

(3) The subjects were unable to give a clear statement of their ocular defects where these were present.

(4) The reflectance methods of measuring hair colour were found to be imperfect.

(5) The subjects were quickly fatigued by the PTC taste test when 8 cups were used in the sorting test.

(6) It was found that the 7-item laterality questionnaire was completed in so little time that it was possible to include

three more items.

5C.3 Computer Program Modification

When the pilot survey data was run through the computer program it was found that there were certain complications owing to the data being in the form of husband and wife pairs. These difficulties were sorted out, but in fact this survey program was never used owing to the failure of the original project.

5D - Eye Colour

5D.1 Total Frequencies of Eye Colours in Sample

It has proved difficult to find any similar work on eye colour for comparison with the results of the present survey. Riddell (1941) in a survey of Scottish schoolchildren found that 8.4% had brown eyes, 48.8% had mixed coloured eyes and 42.8% had blue or blue-grey eyes. These figures would seem to indicate that the present sample of Midland schoolchildren are darker eyed than Riddell's group. In the present survey 47.3% had blue or blue-grey eyes, 35.5% had mixed coloured eyes and 17.3% had dark eyes. However Riddell's classification of eye colour was only nominal and so it is not possible to know how well his divisions correspond with those of the present survey. A slight difference in the classification of dark eyes would account for the difference in frequencies of the two samples. The fact that the two samples are from different regions must also contribute to the variation between them.

Using a nominal scale Wheatcroft (1967) found that 37.4% of a British student group had blue eyes, 41.4% had mixed coloured eyes and 21.2% had brown eyes. These results are in fair agreement with the present survey results.

In a group of white American schoolchildren, Weiss and Murray (1966) found that 33% had brown eyes, 31% had blue eyes and 36% had hazel eyes. This sample cannot be usefully compared with the present survey data as the American population includes a large proportion of dark eyed European migrants. Rozprym (1934) found that 67% of an Eastern European group had light eyes and 33% dark eyes.

An extensive anthropological survey of Ireland was carried out by Hooton and Dupertuis (1955). They collected information on males of all regions of the country but only on females of the West coast area. Since Hooton and Dupertuis found considerable sex differences in eye colour it is not possible to determine whether these differences are true sex differences or merely regional differences. In the Irish males 46.8% had blue or blue-grey eyes, 43.9% had blue-brown eyes and the remainder had pure brown, grey-brown or green-brown eyes. These figures would seem to correspond to Riddell's results but it is difficult to compare two nominal scales with certainty. Hooton (1940) suggests that there is an association between light eyes and dark hair in certain regions of Ireland and it is possible that the slightly increased proportion of light eyed persons in the British sample is due to the inclusion of children of

Irish and Scottish ancestry. (see 3D.1)

5D.2 Sex Differences in Eye Colour

As mentioned in the previous section, Hooton and Dupertuis (1955) found differences between the male sample for the whole of Ireland and the female sample for one region. These West Coast females were much darker eyed than the male whole Ireland sample. In the females 34.2% were light eyed, 23.9% had blue-brown eyes and the remaining 41.9% were dark eyed. It seems probable that these differences are more due to regional variation than to sex differences, however Davenport (1927) quotes previous workers as having found an excess of light eyed males in England so there may be evidence for a sex difference.

In the present sample there were more light eyed males than females, and more females than males in the mixed category. This result would agree with Davenport's data, and it is the result that would be expected if Brues' hypothesis was correct. Brues (1946) suggested that there is a sex-lined dominant factor giving rise to a non-light eye. If such a factor were in operation there would be an excess of light eyed males in affected families. Brues (1950) noted the association of sex and eye colour in a study of 466 sib-pairs. (see 3D.1)

Association of Eye Colour and Hair Colour

see Section 5G.8

Association of Eye Colour and Colour Vision Defects

see Section 5E.5 Colour Vision Defects.

5D.3 Association of Eye Colour and Freckles

The association of eye colour and freckles has not previously been reported. Eye colour is associated with hair darkness, though not in the present sample with the degree of redness of the hair. Therefore it is not likely that the association of freckles and red hair noted in the present survey could have given rise to a spurious association of eye colour and freckles except by reason of a chain of associations. Eye colour is associated with hair darkness, hair darkness is associated with hair redness, and hair redness is associated with freckles. However all of the pigment factors involved in these traits are probably inter-connected. Davenport (1927) has suggested that red haired persons tend to have an additional yellow pigment in their eyes, however this additional pigment if present would change blue eyes to a greenish colour. This would lead to their being included in the mexed eye colour group instead of the light eyed group. In the present survey there was an excess of light eyed freckled persons. (see 3D.2)

5D.4 Association of Eye Colour and Mid-digital Hair

This association was only present in the female sample, but it may be significant that many workers have reported sex differences in mid-digital hair type frequencies. This association has not been reported in any previous work, and the results would appear to show a complex situation with different finger hair types dominating the different eye colour group. However it has been proposed that the presence of mid-digital hair is controlled by a multi-allelic system (Bernstein and Berks, 1942). If such a multi-allele system were interacting with a complex of factors producing eye colour, as suggested by Brues (1946) it would be expected that the result would be association of factors without a clear pattern being apparent. (see 3D.3)

5D.5 Association of Eye Colour and Other Factors

The association of myopia and eye colour noted by Burks (1937) has been mentioned in the section on ocular defects. This was not found in the present survey. Kloepfer (1947) found that besides the usual association with hair darkness, eye colour was also associated with finger length and tongue curling. No association between finger length and eye colour was found in the present survey. Zieve et al (1936) noted that eye colour was not associated with susceptibility to allergic conditions.

5E - Colour Vision Defects

5E.1 Total Frequency of Colour Defects in Sample

In the male UK sample 8.2% were diagnosed as colour defective using the HRR charts. This is in good agreement with Pickford (1969) who quotes a frequency of 7.8% for the general male population of

Britain. Gorrell (1967) found that 7.7% of the adult European males in a Birmingham sample were colour defective. Riches (1966) found a frequency of 3.4% colour defective in East Kentish boys.

In the present sample 6.5% of the total sample were found to have a deutan effect, 1.4% were protan and 0.4% had unclassifiable red/green defects. Gorrell (1967) found that 5.4% of his sample were deutans and 2.3% protans. He also suggests that aging may affect the classification of protans, so it is possible that the youth of the present sample might account for some of the difference between the two samples. However it seems probable that any unusual distribution of types of colour defect found in the present sample would be due to its small size. Pickford (1969) found that 67.7% of a group of 204 colour defectives had deutan defects, but in the present survey 78.3% were deutan.

5E.2 Colour Vision Defects and Natural Selection

The theory that the effects of natural selection can be seen in present day prequencies of colour vision defects has been widely discussed. The main advocate of this theory, Post (1962, 1963, 1965a, 1965b) has suggested that in the earlier days of man the colour defective was at a severe disadvantage both in hunting and in collecting fruits. Using results from many previous surveys Post shows that there are differences between hunting populations, peasant farmers and highly developed populations with regard to the frequency of colour vision defect. It has been suggested (Neel and Post (1963) that the individuals with colour defects in a primitive population would be directed to farming or some less hazardous occupation than hunting. Dutta (1966) found that there were significant differences in the frequency of colour defectives between the stratified occupational levels in India. Both Dutta and Post noted that the highest levels of colour vision defects were found in the most developed groups. Ray (1969) found no difference between urban and rural groups in Orissa but there were significant differences between the different social levels.

Some workers do not support Post's theory. Adam (1969) suggests that colour defects might be an advantage to a hunter as he might be able to see animals that were camouflaged for those of normal sight. Pickford (1969) mentions the case of a pilot with defective colour vision who proved very successful in bombing raids as he was able to 'see through' camouflage. Adam also proposes that it would be the women and children of a primitive tribe that would be involved in fruit picking, and so this would not affect selection against colour vision defects; but he does not consider the disadvantages of the colour defective child in these circumstances. Polyak (1957) has noted the necessity for normal colour vision in fruit picking.

Pickford (1963) points out that the selective disadvantages of defective colour vision are not all past. Confusion could arise with road signals and car brake lights, but in practice colour defectives usually manage to differentiate the confused hues by differences in their saturation and brightness. In a survey of art school students, Pickford found that 5.4% of the males were colour defectives, however all were coping adequately with their studies. Colour vision defects have been implicated as a possible cause of shooting accidents by Neel and Post (1965). They noted that 60% of the hunters involved in shooting accidents in Minnesota were colour defectives, and of these defectives, 75% did not realise that they possessed this defect.

5E.3 'Natural Selection' Effect in Present Sample

Salzana (1963) suggests that it is necessary to exercise caution in the interpretation of colour vision surveys, as more data is needed before Post's theory can be full investigated. Nevertheless Vics (1966) suggested that there might be an association between colour vision defects and high intelligence. This suggestion combined with Post's ideas would lead one to expect an excess of colour defective boys in the grammar school and professional samples. In fact there was a 1.2% difference between the grammar and secondary modern schools in favour of the grammar schools. This cannot be interpreted as conclusive evidence in either direction. In comparing the social class groups it appears that there are more colour defectives at the extremes of the social class scale than in the middle class. The slight excess in the professional group is in accord with Post's theory, but the excess in the manual group cannot be explained. It is known that extremely disadvantageous conditions such as schizophrenia (Hare 1955, Stein 1957) and chronic bronchitis (Meadows 1961) will cause the sufferer to descend the occupational class scale. However, it is unlikely that colour vision defects would have such marked effects.

5E.4 Colour Vision Defects and Geographical Background

In a survey of data from servicemen at centres all over the UK, Vernon and Straker (1943) found that the percentage of colour defective males varied from 5.4 in NE Scotland to 9.5 in SW England. Post (1963a) showed that their data can be interpreted as the effect of two clines of colour vision defect, one running from North to South and one running from East to West. In the present survey no significant differences were found by parental background, but this would not have been expected in view of Vernon and Straker's work. The definitions of geographical background used in the survey were on an area basis rather than a longitudinal basis, and therefore areas of expected high and low colour defect frequency would have been combined to form the English and British samples.

5E.5 Association of Colour Vision Defects and Eye Colour

The association of colour vision defects and eye colour has been noted previously by Burt (1945) who studied 3265 subjects, classifying their eyes as light or dark. He found that the frequency of colour defective persons in the dark eyed class was significantly greater than the random expectation. This finding has been confirmed in the present survey, though there is no apparent reason for this association. Vernon and Straker (1943) suggested that the distribution of colour vision defects seemed to follow the distribution of hair colour. Burt (1945) did not find any association between hair colour and colour vision defects. Since there is a close association between hair and eye colour, it might be expected that both hair and eye colour would appear to be associated with defects of colour vision. (see 3E.2)

5E.6 Association of Colour Vision Defects and Ocular Defects

An association between myopia and eye colour has been noted by Burks (1937). It is possible that the association between ocular defects and colour vision defects noted in the present survey is in fact the product of both factors being associated with eye colour. In the present survey this is unlikely as no association was found between eye colour and ocular defects. (see 3E.4)

5E.7 Association of Colour Vision Defects and Chin Type and Mid-Digital Hair

Neither of these two associations has been reported previously. As previously stated the association of mid-digital hair and colour vision defect is only of borderline significance. It is possible that these results and also the associations with eye colour and ocular defects are merely the products of the small size of the sample of colour defectives. In fact only 23 of the 279 males were colour defective. However the data was tested in a simple dichotomous form in each association, and though the results of the association of ocular defects and mid-digital hair with colour vision defects may be doubtful, the associations with eye colour and chin type remain. (see 3E.3, 3E.5)

5F - Ocular Defects

5F.1 Sex Difference in Ocular Defects

The volume of the eyeball triples between birth and adulthood, however the major part of this growth is achieved before the child is three years old. At birth the average axial length is 16 to 18 mm, and in adulthood this is 24 mm, however the average value for a three-year-old is 23 mm. The rate of growth of the eye after the third year is very slow (Hirsch 1964). Slataper (1960) has noted that ocular changes, probably due to elongation of the eyeball, continue until the age of thirty. There is a rapid increase in myopia between the ages of eight and thirteen (Brown, 1938). Hirsch (1952) noted an increase in myopia in the age groups thirteen to fourteen. As with other characteristics involved in the growth spurt at puberty, this increase in myopia occurs one or two years earlier in females than in males. This may account for the notable sex difference found in the present survey as the subjects used were all aged fourteen or fifteen. Another factor that may have increased the sex difference is the reported excess of females with severe myopia and males with slight myopia (Post 1962b). It is possible that males with slight myopia might prefer to cope without wearing corrective glasses, in which case they would not have been discovered in the present survey. (see 3F.1)

5F.2 Frequency of Ocular Defects

Hirsch (1964) states that 10-20% of children become myopic, and Goldschmidt (1966) found that the proportions of myopic conscripts in Sweden varied from 5% to 28% according to social class. Post (1962) reports only 2.3% of English schoolboys with vision defects, 5.5% of Scottish schoolboys and 13.3% of Jewish schoolboys, however this data comes from a survey carried out in 1927 and so it is possible that testing methods have been somewhat altered since then. Since the present survey of necessity lumped all defects under one heading and did not concern itself with myopia alone it seems that the figures of 10.4% full-time wearers of glasses and 11.1% part-time wearers and within the range that would be expected.

5F.3 Association of Ocular Defects and School Type

It may be that the difference in the proportion of the children at grammar and non-selective schools who wore glasses reflects a difference of nurture rather than nature. Iw ould be expected that children involved in academic work would become inconvenienced by ocular defects, and therefore obtain corrective glasses, but those with less academic pursuits might manage without correction. However Goldschmidt (1966) found that 25.5% of conscripts from a professional background were severely myopic, whereas only 9.5% of the skilled conscripts and 5.6% of the unskilled conscripts were defective. Jevons (1957) compared samples of children with ocular defects from grammar,secondary modern and educationally subnormal schools. He found that 74% of the grammar school sample were myopic, as compared with 28% of the secondary modern sample and 24% of the ESN. Hypermetropia was found in 41% of the ESN children, 14% of the secondary modern children and 8% of the grammar school sample. Squints were found in 21% of the ESN children and 18% of the secondary modern children but only 2% of the grammar school children. The most frequently occurring defects differed in each school type. In grammar schools the most frequent defect was myopia, with an occurrence of 74%. In secondary moderns there were 34% anisometropic children and the most frequent defect in the ESN schools was hypermetropia (32%). Jevons suggested that there may be a genetic link between myopia and above-average intelligence. (see 3F.2)

5F.4 Association of Ocular Defects and Eye Dominance

Merrell (1957) found that eye dominance was not associated with acuity of vision, and suggested that it was probably a motor function. However the methods used by Merrell to determine eye dominance differed from those used in the present survey, and so it is possible that slightly different factors were being measured. In the present survey a positive association was found between ocular defects and right eye dominance. As a first hypothesis it had been thought possible that some right handed persons with a defective dominant right eye might tend to use their left eye in the test. Phillips (1960) has suggested that persons using a microscope tend to develop a dominant left eye, for convenience in drawing. If this were the case it would have been expected that a positive association between left eye dominance and ocular defect would be found. In fact only 5.7% of the left eyed males wore glasses, in comparison with 18.3% of the right eyed males. If ocular defects were tending to confuse the testing of eye dominance it would be expected that both right and left eyed subjects would be similarly affected. Owing to the preponderance of right eyed subjects in the population this would result in a bias towards defective left eyed persons in the original hypothesis. The sex difference in this association is an added complicating factor. (see 3F.3)

5F.5 Association of Ocular Defects with Skin Type

The association of ocular defects with the absence of freckles has not previously been mentioned in the literature. This association was present in both sexes. Freckles have been shown to be associated with parental geographical origin, and ocular defects were found to be associated with school type. It is therefore possible that the significant association between school type and parental origin has produced this association. However it must be noted that although the association of school type and parental origin is significant in the total sample and in the females, it is not present in the males, although the total data is not significantly heterogenous. The association of freckles and ocular defect occurs in the samples of males and females, and in the total sample. In the females one of the comparisons (freckles absent, few, many by ocular defect, no defect) does not show a significant association. If the association between freckles and vision defect was spurious it would be expected that this association would appear to be stronger in the females than in the males as does the association of school type and parental origin. (see 3F.4)

5F.6 Association of Ocular Defect and Finger Length

An association between finger length and ocular defect was noted in the female sample. There is a well documented sex difference in the occurrence of different finger length types (see Section 5N.1 Finger Length). Rosler (1957) has shown that the relative lengths of the fingers may continue to change until ossification is complete. Rosler also found that the social classes were different in their proportion of the different hand type. It is possible that the apparent association of finger length and ocular dominance is related to the stage of puberty of the subject. Those who have entered the growth spurt might have achieved their mature hand type and also completed their eyeball growth (with consequent myopia in some cases). If this were the case the sex difference would be explained by the earlier occurrence of puberty in females. Alternatively it may be that the association of finger length and ocular defect is due to the association of both these factors with an undefined social class variable. However finger length has not been found to be associated with social class or school type in this survey, so this is not a probable explanation. (see 3F.5)

Association of Ocular Defect with Colour Vision Defect

See section 5E.6

5F.7 Previously Reported Associations of Ocular Defects with Other Defects

Although Burks (1937) noted an association between myopia and eye colour and Kloepfer (1947) found that cross eyes were associated with hair colour and hair whorl type, there have been few other reports linking ocular defects with other physical traits. Goldschmidt (1966) found what appeared to be a positive association between myopia and height, but he then showed that this apparent link was in fact due to the association of both height and myopia with social class. A report that myopia was associated with measurements of skull and stature was investigated by Baldwin (1964), who found that these relationships did not occur in a Caucasian population.

5G - Hair Colour

5G.1 Association Between Hair Colour Variables

The association between hair darkness and Munsell value can readily be explained, as both these measures are concerned with the darkness of the sample rather than its colour. Similarly hair redness and chroma both measure colour intensity. The association of hair darkness with hair redness, hair darkness with chroma, hair redness with value, and chroma with value, may represent the effects of the interaction of two pigment series in human hair. According to Hanna (1956) there are probably two pigments responsible for human hair colour. The first varies from grey to black, giving the hair darkness while the other varies from yellow to red producing various browns by interaction with the grey to black series. In this case it would seem that higher concentrations of the yellow/red pigment would only be visible as definitely red hair in individuals with low concentrations of the grey/black pigment. Thus an apparent negative association between hair colour intensity and hair darkness is formed, though in fact some of the dark haired individuals will have a strong yellow or red colour masked by the intensity of the dark pigment. Kloepfer (1946) found a significant association between hair colour (red - not red) and hair shade (darkness).

In consideration of the results of the comparisons of Munsell hue and hair darkness and redness it must be remembered that the hue was judged from an isolated hair sample whereas the colour was judged from the whole head of hair. This may account for the disparity between the hue and redness results. It was found that the majority of those classified as having definitely red hair would also be classified as hue 7.5 YR (reddish) as opposed to hue 10.0 YK (yellow to brown). However it was found that 40.7% of these samples were classified as hue 10 YR. Nicholls (1967) has stated that there is great variation in the colour of the hairs of red haired persons, and so it is possible that unrepresentative hair samples were taken in some cases. It may be that the general impression of the whole head of hair gives a better estimate of the true hair colour than does a small and isolated sample. Steggarda (1941) found that long hair was easier to match using a standard range of hair colours. (see 3G.2)

5G.2 Association of Hair Colour With Sex

All of the hair colour variables were significantly associated with sex, the hair of the girls being in general lighter, redder and with greater colour intensity. One suspicion that might arise from these results would be that the female subjects had altered their natural hair colour by bleaching or adding colourants. However each female subject was questioned on this point, and none admitted using colourants. In a few cases where hair had been lightened there was a clear line of division between the treated and untreated hair, and the darkness and redness were scored on this true hair colour. It is possible that variations in hair care might account for the differences in hair darkness and hair redness as it might be expected that the hair of the boys would be washed less often and therefore be dirtier and greasier. Steggarda (1941) noted that hair was darkened by dirt and grease. But since the hair samples were thoroughly washed before comparison with the Munsell scales this possible error should have been eliminated in the chroma and value comparisons. Increasing age is known to darken hair colour, but in this case the age range of both sexes was controlled. If hair pigment was affected by puberty it would be expected that the females in the present sample would show the darker hair than the males. Owing to the age range the females in the main have completed their growth spurt whereas some of the males will still be in an active phase of change. A sex difference in colouration was noted by Parsons (1920) and by Fleure and James (1916). In both cases the females were darker than the males which is the reverse of the present situation. (see 3G.3)

5G.3 General Frequencies of Hair Colours in the Present Sample

The general frequency of definitely red hair in this population is in agreement with most estimates of the percentage of this trait in Europeans. Steggarda (1941) found that 4.1% of a Dutch group were red haired and van Herwerden and Baele-Nyland (1930) found 2% of Dutch students had red hair. In a study of hair colour in Wales Fleure and James (1916) found that 7.3% of the males and 5.3% of the females were red haired. Parsons (1920) using data from all over Britain found that red hair was present in 4.4% of the males and 4.9% of the females. The present survey results of 4.8% red haired males and 4.1% red haired females would appear to show that the frequency of red hair in Britain has not changed apparently since Parsons' work, which in fact used data collected in 1885. Riddell (1942) found red hair in 4% of a Scottish population and Wheatcroft (1967) noted 2.7% of a British student group were red haired.

In a survey of Ireland, Hooton and Dupertuis (1955) found that 42.0% of the males were dark or black haired, 34.7% brown haired, 10.4% light haired and 9.5% red haired. Among the females the comparable frequencies were 55.7% dark or black, 21.9% brown, 8.7% light and 11.0% red (the remainder were white haired). Fleure and Davies (1958) noted that 68.5% of Welshmen were dark haired and 31.5% light haired. Van Herwerden and Baele-Nyland (1930) found that 38.9% of Dutch students were fair haired, 50.5% had darker blond and 8.3% had black hair (the remainder being red haired). Riddell (1942) found that 15.0% of a Scottish population had light brown hair, 61.0% medium brown hair and 20% dark brown hair. A group of British students examined by Wheatcroft (1967) contained 42.1% light haired, 35.8% with medium brown hair and 19.4% with dark hair. It is hard to compare these results with the result of the present survey as the scales of classification are not standard. In the case of the Munsell classifications it has not been possible to find any other survey data for comparison, though this system is recommended for anthropological work. (see 3G.1)

5G.4 Association of Hair Colour and Social Class

Parsons (1920) noted that there were more red haired parsons in the upper classes than the lower classes though the differences were slight. In London 5.1% of the upper classes were red haired as compared with 4.3% of the lower classes, while in Bristol the comparable figures were 4.3% and 3.8%. In the present survey there were no social class differences in any of the four hair variables, and the definitely red haired subjects made up 5.6% of the total manual group in comparison with 2.0% of the professionals and 5.0% of the middle class. (see 3G.5)

5G.5 Association of Hair Colour and School Type

Though there were no significant differences between the school types with regard to hair colour it would appear that the non-selective school children were rather lighter haired and more red haired than the grammar school children. These differences may reflect the differences in parental origins of the two samples rather than any real association with school type. (see 3G.4)

5G.6 Association of Hair Colour and Parental Origin

Hair darkness, chroma and value showed no association with parental origins. Sunderland (1955) found that there was a gradient of hair darkness across Britain, darkening from East to West. However the classification of the regions in this survey would not bring out any such difference if it occurred. Hair redness was significantly associated with parental origins, but although the proportion of definitely red hair was highest in the British, the most striking difference was in the proportion of non-red hair. The Midland and British groups contained similar percentages with non-red hair, but in the English group this class was very much larger. The proportions of non-red hair in the three groups were 25.6% for the English, 13.1% for the Midland group and 14.6% for the British. Definitely red haired subjects formed 5.8% of the total British sample but only 4.2% of the Midland group and 3.6% of the English. It is generally accepted that there is a higher frequency of red haired persons in the Celtic races (Fleure and James, 1916, Sunderland 1955). In this case the increased percentage of red haired subjects in the British sample would be expected, but the excess of subjects with non-red hair in the English sample cannot be explained. It may be that the Midland group has a long-standing mixture of Irish, Scottish and Welsh industrial workers who have now become identified as native Midlanders. This explanation could account for the differences between the Midland and English samples, but the difference could also be a real one. (see 3G.6)

5G.7 Association of Hair Colour and Hair Form

It is possible that hair darkness, chroma and value are associated with hair form together and that the association of hair form with hair redness is independant. It was noted from the results of the above association that hair redness was only associated with hair colour in males, whereas hair darkness and chroma are significantly associated in the female sample and the total sample, and value is associated with hair form only in the total sample. In view of the sex differences in all four hair colour variables it might be expected that the single sex samples would differ in their results. The association of hair darkness and hair form has previously been noted by Kloepfer (1946) in a linkage study. It is of interest that both hair form and hair darkness have been found to be significantly associated with weight in the present sample. (see 3G.7)

5G.8 Association of Hair Colour and Eye Colour

The association of hair darkness and eye colour is well established (Parsons 1920, Kloepfer 1946). MacConnaill (1942) noted that blue eyes and blond hair were significantly associated and suggests that the four basic combinations of hair and eyes (blue/blond, dark/blond, blue/dark and dark/dark) represent a variety of developmental types. Hooton (1940) put forward the view that the combination of light eyes and dark hair is specifically Irish, and MacConnaill suggests that the population of the British Isles is genotypically light eyed and light haired. (see 3G.8)

5G.9 Association of Hair Redness and Skin Type

This association is also well established. Nicholls (1967) suggested that a single factor may control both hair redness and skin type, giving red hair and freckles in the homozygote and dark hair with freckles in the heterozygote. In the present survey there was a striking association between the presence of red hair and the presence of heavy freckling. Only one case was found with red hair but no visible freckles, and it must be remembered that the presence of freckles is subject to environmental effects. Hair redness and skin type have also been found to be associated with weight in the present survey. (see 3G.9)

5G.10 Association of Hair Redness and Ear Type

Both hair redness and ear type show significant sex differences. Free ear lobes were more common in males, and in the hair redness comparison the male group contained a higher percentage of non-red haired subjects than the females. In the association of hair redness and ear type, it was noted that the group with free ear lobes also contained the greatest frequency of non-red hair. It is possible that this apparent association has occurred owing to the sex differences of both characteristics. (see 3G.10)

5G.11 Association of Hair Darkness and Hairline

It might be expected that there would be a negative association between hairline and hair darkness simply because of the difficulty of observation of hairline irregularities in fair subjects. The hairline in a dark haired subject is easily traced, but in some very fair persons the hairline blends into the small facial hairs without a definite margin being visible. In such cases it is difficult to distinguish irregularities and it is possible that some cases with widow's peaks could have escaped classification. (see 3G.11) The fact that the female sample also shows a trend towards fair hair being associated with the lack of a widow's peak supports this theory. However the variation in the proportion of persons with dark brown hair in the various categories cannot be explained. It would be expected that dark brown hair would exaggerate any hairline irregularities that were present, so it must be presumed that the results do represent the actual proportions of the hairline types. The excess of dark haired males with irregular hairlines and the complete lack of either dark brown haired males with widow's peaks or dark brown haired females with irregular hairlines might be explained by the small size of the group with dark brown hair. It is also possible that the sex difference in hairline associated with the sex difference in hair darkness is acting to provide these results.

<u>Association of Chroma and PTC</u>

See section 5P.13

<u>Association of Hair Colour and Weight</u>

See section 5R.13

<u>Association of Chroma and Ponderal Index</u>

See section 5R.15

<u>Association of Chroma and Height</u>

See section 5R.15

5H - Hair Form

5H.1 General Frequencies of Hair Form Types

In a study of a student population, Wheatcroft (1967) found that 60.8% had straight hair, 33.9% had wavy hair and 5.3% curly hair. In this case hair form was classified on a purely nominal scale. It would seem that the present survey results indicate a difference in classification rather than a real frequency variation. In the 1967 survey a three-class scale was used whereas in the 1968-9 survey a four part scale with a standard range of hair curls was used.

It seems probable that some of those classified as straight haired in the first survey would have been grouped as slightly wavy in the second survey, as only 39.7% of the school children were noted as straight haired. The division of those with wavy hair into two classes according to the degree of wave also complicates any comparisons.

No significant sex difference was present in the student sample (Wheatcroft 1967). A sex difference was reported by Kloepfer (1946) and Scheinfeld (1965) notes that there are more wavy haired males than females.

Differences in social class and school type have not previously been reported. It seems unlikely that the school type result was due to a learning effect in the use of the hair form standard range, and it should be noted that the classification of parental occupation occurred at the base laboratory after the sampling was completed. (see 3I.1)

5H.2 Association of Hair Form and Foot Preference in Kicking

It has been noted that there is a significant association between hair form and weight and between weight and foot preference in kicking. It is therefore possible that the reported association of hair form and kicking is the result of both these factors being associated with the weight of the subject.

However it cannot be established which factors are dependent on each other in a triangular relationship such as this, as hair form and weight are associated significantly only in males, whereas hair form and kicking preference are only associated in females. (see 3I.2)

Association of Hair Form and Hair Colour

See section 5G.7

Association of Hair Form and Weight

See section 5R.11

Association of Hair Form and Height

See section 5R.11

Association of Hair Form and Foot Width

See section 5R.11

5I - Hair Line Type

5I.1 General Frequencies of Hair Line Types

Wheatcroft (1967) found that 8.5% of a student group had widow's peaks. This proportion of subjects possessing definite widow's peaks would appear to be very different from the present study where 17.3% had peaked hair lines, but it is possible that this difference is in fact due to differences of definition between the two surveys. Only very definitely peaked hair lines were scored in the student survey as the survey conditions were unfavourable. In the present survey it was possible to examine each subject's hair line using supplementary lighting. It is therefore likely that some of the peaks noted in the school sample would not have been recorded if they had occurred in the student sample. (see 3J.1)

5I.2 Association of Hair Line Type and Sex

There was no significant sex difference in the British student sample (wheatcroft 1967) though there were slightly more males with widow's peaks than females. In these males 9.2% had widow's peaks and 7.2% of the females shared this trait.

In the current survey the sex difference appeared to be centred on the widow's peak groups, as 21.6% of the males belong in this class as compared to only 13.6% of the females. The difference for the intermediate type hairline is not so great. This type of hair line is present in 18.3% of the males and 15.1% of the females.

This sex difference in hair line type has not previously been reported. It is possible that the increased frequency of peaked hair lines in males is in some way associated with the development of facial hair. (see 3J.1)

5I.3 Association of Hair Line Type and School Type

As in the case of the association of chin type and school type, it could be argued that this association might be an artefact produced by the non-random visitation of the two school types. However the majority of the grammar schools were visited before the sampling of the secondary modern schools began. If there had been a learning effect in classifying the hair line type it would have been expected that more positive results would have been recorded as the survey progressed.

In this case it is found that the grammar school group, who were sampled first, had the higher frequency of widow's peaks. This relationship was present in the total sample and in both the male and female sub-samples.

Assuming that the association is valid, it is possible to suggest the explanation of a difference in gene frequency in the two populations. However the heritability of this trait has been shown to be only 0.39 and it is also possible that environmental factors may be responsible for this difference. The presence of a widow's peak is apparent even in babies of one year (see fig. 11).

Fig. 11. Triplets aged 1 years showing widow's peak

(Right and centre are identical)

The illustration shows one-year-old triplets two of whom are identical and have identical widow's peaks. If environmental factors affect the expression of the widow's peak characteristic it is probable that these effects occur during embryonic development. (see 3J.1)

5I.4 Association of Hair Line Type and Mid-digital Hair

This association was only present in the males, but this sex difference is not unexpected in a trait where the sexes differ significantly. Setty (1964) has divided the hair patterns of the hand and arm into five types. He found that mid-digital hair was only present on two of these hair types, and it was not found in all of these subjects.

In a later paper Setty (1966) also noted a possible association of hand hair pattern and MDH types. It may be that the presence of a widow's peak is a part of a whole body hair pattern that also includes mid-digital hair types. No other worker had noted this association, Montagu (1962) suggested that the function of head hair was to protect the scalp from excesses of heat and cold as there is no adipose tissue in this region. It is difficult to suggest any adaptive significance for the widow's peak. (see 3J.2)

Association of Hair Line Type and Hair Colour

See section 5G.11

5J - Ear Lobe Type

5J.1 Sex Differences in Ear Lobe Type

Before one can discuss the general frequencies of ear lobe type it is necessary to review the sex differences affecting this trait. This difference has been reported in many past surveys. Where a sex difference does occur it takes the form of an excess of females with attached ear lobes. Dronamraju (1966) found significant sex differences in both American whites and American negroes. Riddell (1941) found a significant excess of females with attached ear lobes in two Scottish samples. A significant sex difference in the ear lobe types of Tibetan refugees was discovered by Tiwari and Bhasin (1969). Hooton and Dupertuis (1955) found a greater frequency of attached and fused ear in females. They also noted that 45.2% of the males had large lobes but only 2.6% of the females were classified thus. Gates (1954) also noted that males had larger ears, and stated that the frequency of attached ear lobes in females is twice the frequency in males. A significant sex difference in this characteristic was also present in a sample of British students (Wheatcroft 1967).

Other workers have not found any significant sex differences, but these results usually come from isolated populations. Lui and Walsh (1966) found no sex difference in New Guinea natives, and Dutta and Ganguly (1965) found no sex difference in a population of Nicobarese. However Kloepfer (1946) found no sex difference in family studies in America.

In view of this well established sex difference, it would seem that the significant sex difference found in the present survey is in agreement with the majority of past work. It has been stated that ear lobe types tend to change slightly with age, Vollmer (1937) states that the ear is free in childhood, then it becomes more adherent, only to become free again in old age. Dronamraju (1966) noted that it was difficult to decide on the ear lobe type of persons over seventy as their ear lobes tended to sag. If there were any large change from free ear lobes to attached ear lobes during childhood and adolescence it might be expected that this would give rise to a transitory excess of females with attached lobes as a result of their earlier growth spurt. However sex differences have been noted in adult populations (Gates 1954, Dronamraju 1966) and it is unlikely that growth changes in ear lobe type would affect any other than borderline cases. (see 3K.1)

5J.2 General Frequencies of Ear Lobe Type

Dronamraju (1966) found that 58.2% of American white males and 44.0% of American white females had free ear lobes. Hooton and Dupertuis (1955) in their Irish sample found that 58.2% of males and 40.9% of females had free ear lobes. In the present survey 43.3% of males and 32.5% of the females were classified as having free lobes. The survey by Hooton and Dupertuis only classified ear lobes as free or attached. It therefore seems possible that in the present survey some subjects are being classified as intermediate who might in a two class system have been put into the free ear lobe group. However the survey by Dronamraju classified ear lobes into three types; free, intermediate and attached. In this investigation only 10.2% of the males and 36.0% of the females had attached ear lobes as compared with 37.2% of males and 46.7% of females in the present survey. It is possible that these differences are due to national differences between the samples. Glass et al (1952) in a comparison of a religious isolate in America with the general population quotes the figure of 59.5% with free ear lobes for the general population. In the religious isolate Glass found 74.7% had free ear lobes, and a later study of different generations in a religious isolate (Glass 1956) confirmed that the proportion of free ear lobes differed from the general population.

It has not been possible to find a survey involving English subjects for a direct comparison with the present data. Dutta and Ganguly (1965) found that 58.9% of the males of the Gandhabanik caste of West Bengal had free ear lobes, whereas only 20.3% of male Nicobarese and 19.9% of female Nicobarese were put into this class. Dronamraju (1966) found that 47.9% of American negroes had free ear lobes, 20.3% had intermediate lobes and 32.9% had attached lobes. The percentage of males with free ear lobes ranged from 18% to 55% in a survey of Indian regional groups carried out by Das (1967). In Tibetan refugees attached ear lobes were more common than free lobes. Tiwani and Bhasin (1969) found 57.2% had attached ear lobes, 20.4% had intermediate lobes and only 22.4% free lobes. Bhasin (1969) also found that 49.1% of male Depalese had attached or lobeless ears. Lai and Walsh (1966) found that 65.6% of New Guinea natives had attached ear lobes, and quote values ranging from 22.0% for Australian aboriginals to 65.3% for Filipinos.

As there are no comparable figures it is difficult to draw any conclusions from the small differences between school type, social class groups and parental origin groups. The work of Glass (1956, Glass et al 1952) has shown that the factors affecting ear lobe type are susceptible to population changes. However the religious isolate is a rigidly defined unit and cannot be equated with different social class groups either in terms of size or isolation. (see 3K.1)

Association of Ear Lobe Type and Hair Redness

See 5G.10

5J.3 Association of Ear Lobe Type and Chin Type

Since ear lobe type has been shown to be associated with sex it is not unexpected that the association of ear lobe type with other factors should differ in the two sexes. The association of free ear lobes and a non-cleft chin in males has not previously been reported. It might be that there is some developmental link between the lower jaw and its musculature and the attachment of the ear lobes. An attached ear lobe joins the cheek at approximately the proximal end of the jawbone. Krogman (1965) has suggested that the presence of a cleft chin is related to the structure of the jawbone.

This association is further complicated by the sex differences in chin type. Though these differences were not statistically significant in this survey it was found that 35.1% of males had a chin cleft but only 28% of the females. Both the traits in this association are sex influenced to some degree. However if a simple relationship between the two traits existed it would be expected that the characteristics most frequent in males would show a positive association; that is free ear lobes and cleft chin. The results show that in males free ear lobes are associated with a non-cleft chin and attached ear lobes with a cleft chin. In the female sample, where the association is not significant, free ear lobes are associated with a cleft chin and attached ear lobes with a non-cleft chin. (see 3K.2)

5J.4 Association of Ear Lobe Type and Secretor Trait

This association was only present in the female sample, and it has not been noted previously. The present result may have been affected by the lower sample size in this comparison, but in fact 169 females were used in this test. The comparative figures seem to indicate that there is an excess of secretor females with attached or fused ears, while the most common group in non-secretors are those with intermediate ears. In the secretor females 50.4% had attached ears as compared to 35.5% of the non-secretors. (see 3K.3)

5J.5 Association of Ear Lobe Type and Other Factors

Brues (1950) investigated relationships of a number of traits, including ear lobe attachment, by means of a study of sib-pairs. She found that ear lobe type was not linked with height, weight, ponderal index, eye colour, iris structure, freckling, hair colour or hair form. In a family study Kloepfer (1946) noted that while ear size was associated with PTC and MBS tasting, and ear flare (from head) was associated with finger length, eye colour and blood type, ear lobe attachment showed no association with the traits included in the survey. These traits included PTC tasting, mid-digital hair, hair whorl, hair curl, hair colour, ear size, ear flare, eye colour, cross eyes, tongue curl, warts, finger length and sex.

5K - Chin Type

5K.1 General Frequencies of Chin Type

The only data that was available as to the occurrence of the different chin types in the general population was the British student population studied by Wheatcroft (1967). In this group 18.6% had cleft chins.

It is accepted that the method of classification used is far from perfect, and this may account for the high overall frequency of cleft chins. However the general category "cleft chin" includes all those subjects whose degree of chin indentation is in fact only slight. These cases form 18.3% of the total, thus reducing the cleft chin frequency to only 13.0%. In a student group (Wheatcroft 1967) a significant sex difference was present, this is in agreement with the trend found in the present survey. (see 3L.1)

5K.2 Association of Chin Type and School Type

Unfortunately the order in which the samples were collected from the two types of school was not random, most of the grammar schools being visited before the secondary modern. This means that any association of an anthroposcopically classified trait with school type must be subject to certain reservations. It is possible that the increased frequency of cleft chin noted in the secondary modern schools was due to some learning effect on the part of the investigator. This is not believed to be the case, as the standard range of chin types was used for reference throughout the entire survey. There have not been any previous reports of this association. (see 3L.1)

5K.3 Association of Chin Type and Social Class Group

This association is not subject to the reservations noted in the previous section as the classification of the father's occupations was not carried out at the time of the survey but at a later date. It is of course possible that the association of school type and social class could lead to an apparent association that was in fact spurious, but this does not seem a probable explanation of the results.

It is unfortunate that no data on the distribution of chin types in the British Isles is available in view of the significant association of social class and school type with parental origin. It is possible that the underlying regional differences between the social class groups in this sample could give rise to the present association. (see 5L.1)

Association of Chin Type and Ear Type

See section 5J.3

Association of Chin Type and Colour Vision Defect

See section 5E.7

5L.1 General Frequencies of Freckling

Hooton and Dupertuis (1955) found that freckles were present in 40% of Irish males and 48% of Irish females. The present survey result of 54.7% males and 56.3% females in unexpectedly high. However Scheinfeld (1965) has noted that freckling may be transitory appearing in childhood and disappearing at maturity. It is possible that the high frequency of freckling in the present survey is due to the relative youth of the survey subjects. In a survey of Birmingham students, Wheatcroft (1967) found that 56.2% of the females were freckled, but only 31.5% of the males. It is possible that there are hormonal effects on skin pigmentation at puberty. This would account for the lack of any sex difference in the present survey while it is clearly present in the adult sample of Hooton and Dupertuis, and it is found to be significant in the young sample of Wheatcroft. (see 3M.1)

Association of Skin Type and Eye Colour

see section 5D.3

Association of Skin Type and Ocular Defects

see section 5F.5

Association of Skin Type and Hair Colour

see section 5G.9

Association of Skin Type and PTC Tasting

see section 5P.11

Association of Skin Type and Weight

see 5R.11

Association of Skin Type and Height

see section 5R.12

Association of Skin Type and Foot Length

see section 5R.12

5L.2 Association of Skin Type and Stamping Foot Preference

It has been noted elsewhere in this report that skin type was associated with weight, and that a number of laterality variables were also associated with weight. It is therefore possible that the present apparent association between skin type and stamping foot preference is due to both these factors being associated with weight. However it is found that foot preference for stamping is not associated with weight, though foot preference for kicking is significantly associated in bothsexes. This association has not been noted in any previous survey.

5M - Mid-digital Hair

5M.1 Population Frequencies of MDH Types

In populations of European origin the various types of MDH pattern in frequency in the following order: MDH 0 most common, then MDH 3, MDH 1, MDH 2, MDH 4 and rarely other combinations. This order was noted by Danforth (1921) and Bernstein and Burks (1942). Glass et al (1952) found that MDH 2 was commoner than MDH 1 in a group of American whites, but the order was otherwise unchanged. A religious isolate study in America, (Glass et al 1952) produced the sequence MDH 0, MDH 1, MDH 3, MDH 2, MDH 4, but this group were known to differ from the general population in many respects. In an Indian group, Srivastara (1966) noted that of those with mid-digital hair MDH 1 was the most frequent type with MDH 2 and MDH 3 following in sequence.

In the present survey the relative proportions were in descending order MDH 0, MDH 2, MDH 1, MDH 3 and MDH 4. There is therefore a considerable difference between this data and that of Danforth (1921) and Bernstein and Burks (1942), though this difference occurs only in the relative frequencies of different classes of persons possessing hair. The percentage of persons without MDH in the present sample was 39.4%, this is in fair agreement with the figures of Danforth (32.7%) and Bernstein and Burks (31.0%). It would seem probable that this variation is due to the different racial origins of the samples. Bernstein and Burks (1942) noted that the Irish and Italians had less mid-digital hair than other Europeans. Bernstein

(1949) suggested that the gene frequencies for the factors controlling the expression of mid-digital hair formed clines over Europe. She proposes that the factor for MDH 3 is centred on North Europe while the factor for MDH 2 is most prevalent in the Alps, Southern Germany and Northern Italy. MDH 0 is most frequent in Sweden and Ireland, while the factor producing MDH 1 is found in South-East Europe. Similarly Dutta (1966) suggested the existence of clines of MDH frequencies across India.

However Brothwell and Molleson (1965) showed that there was regional variation within Britain. They compared the frequency of persons with MDH in samples of adults from Yorkshire (who were born of Yorkshire parents) and from within 40 miles of London. In the Yorkshire group 33.9% of the males and 43.4% of the females lacked MDH, but in the London group MDH was absent in only 21.7% of the males and 17.1% of the females.

Many racial differences in MDH frequency have been observed. Garn (1950) quoted percentages of persons with MDH including 66.9% of Boston males and 66.7% of Aleut males. Danforth found that 61% of American white males had MDH, and Slatis (1964) noted its presence in 49.0% of this group and 15.0% of US negro males. Garn (1950) noted MDH in 67% of adult white US males, while Beckman and Book (1959) found that 71% of a Swedish sample possessed MDH. Dutta (1966) found that the percentage possessing MDH in a range of Indian populations varied from 26% to 66%. He suggested that there may be clines of gene frequency across India. Basu (1967) noted that 55.5% of Indian males in Maharashtra had MDH, and Dutta (1965) noted that 50% of the males in Orissa possessed MDH. He also states that the frequency varies between 76% and nil in Indian populations, and notes significant differences between upper and lower castes. Tripathy (1963) found a MDH frequency of 32.3% in males in Orissa and Srivastara (1966) noted its presence in 48.1% of the males in Lucknow. In the Nicobar Archipelago MDH was present in 78.7 to 75.4% of the islanders (Ganguly and Pal 1963), but in the Anadan islanders MDH was only present in 36.5% of the males (Agrawal 1965). Tiwari and Bhasin (1967) found that 44.3% of Tibetan females had MDH. Sewall (1939) found MDH in only 1.3% of Eskimos.

5M.2 Sex Differences in MDH Frequencies

A sex difference, sometimes significant, has been reported in many samples. Danforth (1921) found that only 44% of US females had MDH as compared to 61% of the males. Garn (1950) noted that 66.7% of Aleut males had MDH but only 41.7% of the females and 21.5% of the children. Bernstein and Burks (1942) noted that the appearance of a sex difference was influenced by the age of the sample. In a group under 18 years old there was no sex difference but in those aged 21 and over there were significantly less females with mid-digital hair. Saldanha and Guinsberg (1961) compared MDH frequencies in groups of Brazilian schoolchildren before and after puberty. In the males there was a significant difference between the groups, but this did not occur in the females. The pre-puberty male group contained 50.8% with MDH compared to 68.2% in the post-puberty group. This would seem to indicate a hormonal effect on mid-digital hair growth. Tiwari and Bhasin found a significant sex difference in Tibetan children with mean ages of 13.6 for females and 14.7 years for males. However Agrawal (1965) found no sex difference in Andaman Islanders.

It has been suggested that some females have rudimentary MDH which is not detected at examination (Danforth 1921) or that housework has the effect of reducing MDH in the mature female. However the hormonal effect explanation seems to be more relevant to the data of Saldanha and Guinsberg (1961) and that of Garm (1950), who found a reduced frequency of MDH in castrated males. He also noted the case of a female with a virilizing ovarian tumour who had mid-digital hairs one centimetre long.

The absence of any significant sex difference in the present survey is probably due to the youth of the sample. However all those included in the sample were either fourteen or fifteen, so the majority of the girls should have been at the post-puberty stage, though not all the boys. It is possible that a spurt in MDH growth occurs at the end of puberty in males, but a longitudinal study is required to check this possibility. (see 3N.1)

<u>Association of MDH and Eye Colour</u>

see section 5D.4

<u>Association of MDH and Colour Vision Defect</u>

see section 5E.7

<u>Association of MDH and Hair Line</u>

see section 5I.4

Association of MDH and PTC Tasting

see section 5P.12

5N - Finger Length

5N.1 Basic Frequencies and Sex Difference

Mixed sex sample frequencies are rarely quoted for this trait because of the extreme sex differences which have been noted by Blincoe (1962), Phelps (1952) and George (1930). The present survey found that 32.3% of the males had long index fingers, 18.3% had equal ring and index, and 49.5% had a long ring finger. These figures are in fair agreement with the existing data. George (1930) found that the relative proportions in males 28% long index, 17% equal and 55% long ring. Blincoe (1962) noted 22.2% of males possessed long index fingers, 26.0% equal ring and index and 51.8% long ring, and in Phelps' data the proportions were 27.0%. 13.8% and 59.2%.

The females of the present survey included 45.6% with long index fingers, 22.0% with equal fingers and 32.4% with long ring fingers. In George's female sample there were 52.0% with long index fingers, 24.0% with equal fingers and 24.0% with long ring fingers. Blincoe found that 45.0% of the females were in the first class, 25.5% had equal fingers and 29.5% fell into the remaining group. Phelps (1952) noted that 56.8% of his female sample were classified as long index finger type, the remainder being made up of only 12.6% with equal fingers and 30.5% with long ring fingers.

Any variations of the present survey data from the quoted figures might be due to differences in the ages of the samples. All the work quoted involved adult subjects, but the present survey has only included schoolchildren. Rosler (1957) notes that finger type changes at adolescence. It would seem that this sex difference has some hormonal basis. It might be argued that as manual labour can alter finger type (Rosler 1957) the variation was due to the heavier manual tasks performed by males. If this difference were purely environmental it would not be fully developed in the present survey group who had not begun any regular occupation. It is unlikely that sex differences in the school curiculum would be sufficient to create the hand type differences noted. (see 30.1)

5N.2 Association of Finger Type and Social Class

Rosler (1957) noted that the long ring finger type was most common among manual workers and the long index finger type among skilled and white-collar workers. No comparable association was found in the present survey. There was an excess of long ring finger females in the non-selective schools, but this difference was not significant, and in general the frequencies for the two school types were very similar.

In the social class group comparisons the greatest frequences of the long ring finger type were found in the professional group in the males and the manual group in the females. The social class differences were not significant. It would seem likely that the sex difference may confuse the data in this characteristic. (see 30.1)

Association of Finger Type and Ocular Defect

see section 5F.6

5N.3 Association of Finger Type and Writing and Unscrewing a Jartop

Associations of finger type and laterality have not previously been noted. However in this case these associations may be due to the use of the left hand in classifying finger type. The original aim of this method was to avoid the environmental effects on the muscles of the dominant hand, but owing to the low frequency of left handed persons it was not thought necessary to examine their right hands. It had not been expected that environmental muscle building would produce any effect on finger type.

The finding of an increased percentage of left hand users in the long ring finger group might be interpreted as a true association of the traits. But it is also possible that there is an increased frequency of long ring finger type in the dominant hand owing to its extra use. In a sample where the only dominant hands included were left ones, a spurious association might appear. However it was noted (section 5Q.7 Laterality) that all the manual activities included in the laterality study were closely associated with each other. It would be expected that more laterality traits would be associated with finger type if the association were due to the dominant hand effect. Another possibility is that it is only very specialized activities such as writing and unscrewing a jar top that develop the muscles affecting hand type. In this case the effect of these activities would only be noted in the hand that performed them. (see 30.2 and 30.3)

Association of Finger Type and Weight

see section 5R.16

50 - ABO Secretor Trait

50.1 Basic Frequency of Secretor Trait

Boorman and Dodd (1965) noted that approximately 20% of the population were non-secretors. Race and Sanger (1968) quote the figures of 22.7% non-secretors in an English population and 24.1% in white Americans. In Brazil Palatnik et al (1967) found 18.6% of the white population were non-secretors in comparison with 14.2% of the negroid group and 47.4% of the original negro population. The present survey finding of 23.6% is in good agreement with the figure quoted by Race and Sanger (1968). Any variation around this basic frequency among the sub-groups may be interpreted as an effect of the reduced sample size owing to the difficulty in obtaining samples. (see 3Q.1)

Association of ABO Secretor Trait and Ponderal Index

see section 5R.14

Association of ABO Secretor Trait and Ear Type

see section 5J.4

50.2 Other Associations of ABO Secretor Trait

The ABO secretor trait is closely associated with the Lewis blood group system (Race and Sanger 1968). It has been noted that there is an excess of non-secretors among duodenal ulcer patients (Clarke et al 1959). There is a possibility that immunological factors are involved in the genesis of duodenal ulcers. Another suggestion is that the sperm of a secretor may be at a disadvantage in an ABO incompatibility situation owing to their carrying antigens. However Mayo (1969) disagrees with this view and suggests that non-secretor foetuses are most liable to be lost owing to ABO incompatibility. The interaction of the ABO, secretor and Rhesus systems in the problem of incompatibility is most complex.

5P - PTC Tasting

5P.1 The position of the Antimode in PTC Distributions

In most surveys of PTC tasting the data is reported in terms of two classes; taster and non-taster. Since the distribution is divided at the antimode it would seem that the position of the antimode will determine the proportions in the two classes. In general the antimode is decided by inspection of the survey data, though Kalmus and Maynard Smith (1965) have devised a more accurate method of dividing the distribution.

However some populations lack a clearly bimodal distribution, being unimodal or multimodal. In these cases division of the data into two classes may not be valid procedure. When previous surveys were considered it was found that the position of the antimode varied from solution 2 (Giles et al 1968) to solution 7 (Harris and Kalmus 1949) according to the population studied. Most surveys studied appeared to place the antimode between solutions 4 - 5 or 5 - 6.

In their study of a British population Harris and Kalmus (1949) set the antimode between solutions 5 and 6 for males and solutions 6 and 7 for females. However Sunderland and his associates (Sunderland 1966, Pullin and Sunderland 1963, Cartwright and Sunderland 1967, Partridge et al 1962) have found that solution 4 is an appropriate antimode in British populations. Sunderland uses the method of dividing the number of persons in the antimodal class equally between the two categories taster and non-taster. This can lead to the apparent presence of half subjects in the data.

In the original programming of the present survey it was decided to adopt the antimodal division of Harris and Kalmus (1949). In order to simplify the programming a single division between solutions 6 and 7 was made in both sexes. At this time it had not been fully realised that the weight of more recent surveys showed than an antimode at a lower solution number was to be expected. In fact inspection of the data from the present survey showed that the natural antimode lay between solutions 3 and 4 in both sexes.

5P.2 Previous Surveys of PTC Tasting

The PTC taste polymorphism has been used as a trait for inclusion in anthropological surveys ever since its discovery in 1930. In this time a large number of survey reports have accumulated, referring to population groups as diverse as the Lapps (Allison 1950) and the Jivaro Indians (Sunderland and Ryman (1968). It is not proposed to list these studies in the text, but their results are summarized in Fig. 12.

As mentioned in the preceding section, surveys of PTC tasting in Britain have been carried out by Harris and Kalmus and by Sunderland and his associates. In almost all cases division of the distribution at the antimode gives a non-taster group containing approximately 30% of the population. In Harris and Kalmus' survey of 1949 there were 33.6% non-tasters in a male group and 33.0% in a female group. Pullin and Sunderland (1963) found that 27.6% of a group of Pembrokeshire school children were non-tasters, while Cartwright and Sunderland (1967) recorded 27.5% non-tasters in Lancaster in comparison with 34.0% in Derby. Sunderland (1966) reported 23.8% non-tasters in North-West Northumberland and 31.7% in the south-eastern part of Northumberland. He also quoted 31.5% for S.E. England, 31.8% for County Durham, 32.0% for Scotland, 37.7% for the Orkneys and 29.4% for Liverpool. In a survey of the Black Mountain district of Carmarthenshire, Partridge and co-workers (1962) found that the proportion of non-tasters varied from 17.5% to 43.3% according to the parentage of the group studied. Beach (1953) also noted a raised frequency of non-tasters in a Welsh population, finding that 44% of the population of Plynlymon Moorland area were non-tasters. He also quotes a figure of 29% non-tasters in the general population.

Fig. 12.

Summary of previous work related to PTC tasting in various countries

Author	Date	Population	Antimode	% Non-taster
Agraval, H.N.	1966	Burmese Andanese	4/5	19.7
Allison, A.C.	1951	Kenyan Africans	2/3	8.1
		Eastern Bantu	2/3	3.8
		Melinde Arabs	2/3	25.4
Allison, A.C. & Nevarlinna, H.R.	1952	Norway Lapps	3/5	6.8
		Swedish Lapps	"	7.0
		Finns	"	29.2
Åkesson, H.O.	1959	Sweden	5	32.0
Azevedo, E.	1965	Brazil	5	14.2
Barnicot, N.A.	1949	African negroes	4/5	2.7
Bhattacharya, D.K.	1964	Anglo indians	Single soln.	28.1
Bonné, B.	1966	Samaritan (Israel)	3	6.4
Covarrubias, E.	1965	Pewenche Indians (Chile)	5/6	3.2
Freire-Maia, A. & Quelce-Salgado, A.	1960	Salvadore (Brazil)	5/8	38.0
		Cuntiba (")	5/6	26.0
		Presidente prudente (")	5/7	8.0
Giles, E. et al	1968	Yucatan (Mexico)	2	9.9
Jenkins, T.	1965	Kalahari bushmen	5/6	7.1
		Kgalagadi Bantu	5/6	5.2
		Urban Bantu	5/6	2.3
Johnson, F.E.	1966	American negroes	Paper	6.0
Kalmus, H.	1964	Mexico	4	10.4
Lugg, J.H.W. & Whyte, J.M.	1955	Chinese	6	2.0
		Indian Tamil	6	19.6
		Malay	6	18.0

Author	Date	Population	Antimode	% Non-taster
Lugg, J.H.W.	1957	Malay Negritos	6	18.0
		Senoi	6	4.0
	1966	Japanese	Not bimodal	
		Australian Aboriginal	Not bimodal	
		South Koreans		
Merton, B.B.	1958	Norway	5	30.5
Milunicova, A. et al.	1969	Czechoslovakia	Paper	19.9 (female)
				25.9 (male)
Mohr, J.	1951	Denmark	varied by age group	31.8
Monn, E.	1969	Norway Lapps:	Single sol.	
		Kautokeino	" "	25.8
		Karazik	" "	17.3
		Tarra	" "	12.6
Montenegro, L.	1964	Tucano Indians	4	6.2
Parr, L.W.	1934	12 racial groups	Paper	from 6.0 to 36.5
Romanus, T.	1965	Sweden	Single sol.	18.4 (male)
				12.8 (female)
Saldanha, P.H.	1958	Japanese in Brazil	4/5 male	8.5
			3/4 female	6.1
Saldanha, P.H.	1962a	Brazilian negroes	4/5 or 5/6	5.1
		Mulattoes		13.1 or 16.7
Saldanha, P.H. & Nacrur, J.	1963	Chileans age 16-19	5/6	19.9
		age 20-29		7.7

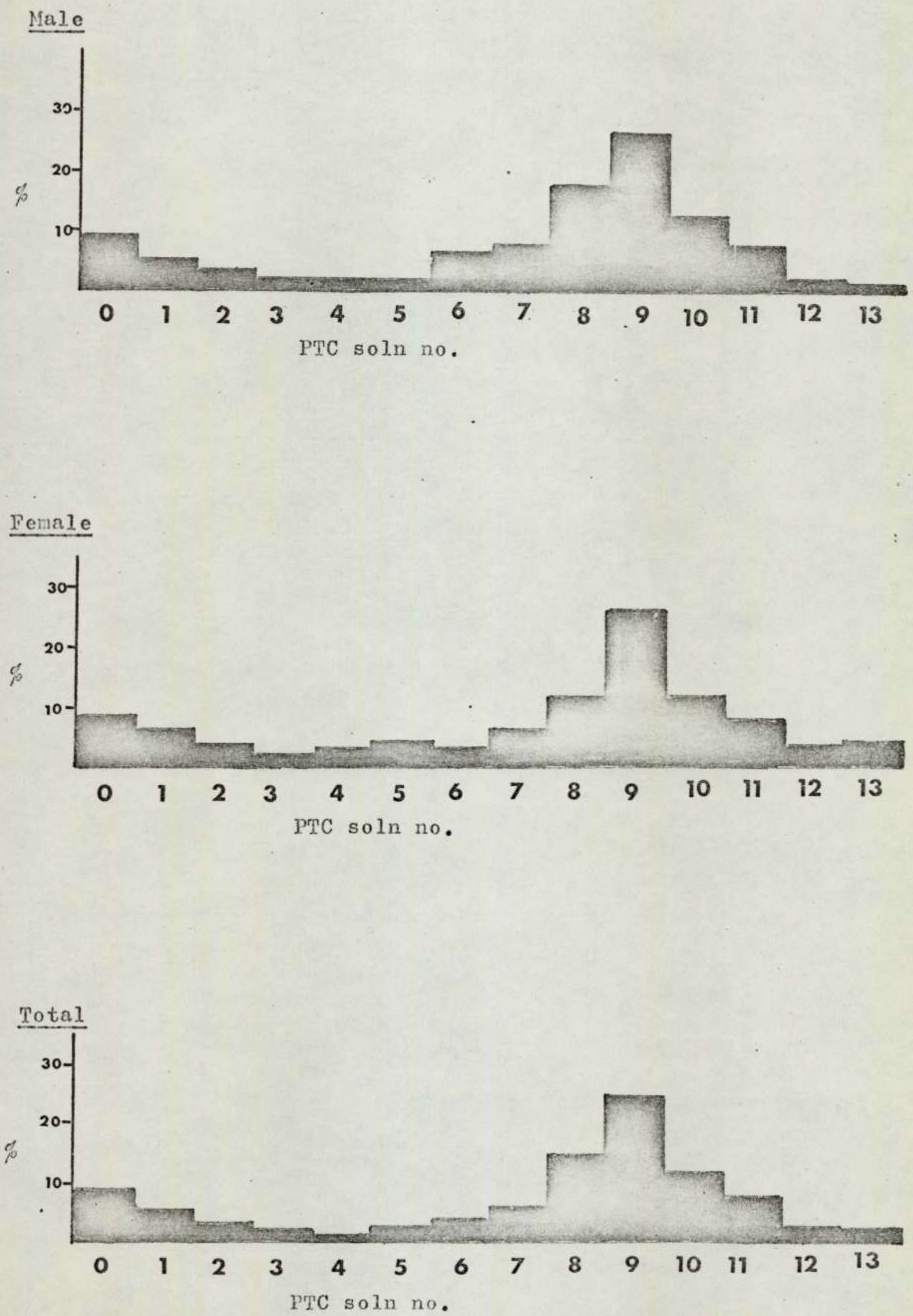
Author	Date	Population	Antimode	% Non-taster
Seth, P.K. et al	1969	Gujars	No method given	49.3
Sheba, C. Adam, A et al	1962	Ethiopian tribes	3	3.9-15.5
Sheba, C., Askenazi, I, et al.	1962	Jewish population groups	5	11.0-41.0
Srivastara, R.R.	1964	Uttar Pradesh	Paper	15.8-18.1
Sunderland, E. & Ryman, R.	1968	Jivaro Indians, Ecuador.	3	2.1

However in the present survey a division at the natural antimode (3/4) gave only 20.0% non-tasters, while division at 6/7, where there was no apparent antimode, gave a more conventional result of 29.9% non-tasters. These proportions were found to be consistent in both sexes. It is difficult to explain this difference between the present survey and the results of previous workers. Taking the antimode between solutions 3 and 4 is in fair agreement with the work of Sunderland, who divides the tasters on solution 4 between the two groups. But Sunderland and his associates have in general reported a frequency of approximately 30% for non-tasters in most regions of the country. The exception to this general trend occurred in North-West Northumberland, where only 23.8% were non-tasters (Sunderland 1966), and in a group each of whom had one parent from the Black Mountains and one from the surrounding area (Partridge et al 1962). The frequency of non-tasters in this latter case was only 17.5%. In it also of interest to note that, although there was no antimode between solutions 6 and 7, the frequency of non-tasters found using this division was similar to that found by Harris and Kalmus (1949).

It is difficult to explain this unusual percentage of non-tasters. There is no ambiguity in the data regarding the position of the antimode, and Sunderland's work would support this. But in this case there would seem to be 10% fewer non-tasters than had been expected. Adopting Harris and Kalmus' antimode without regard for the shape of the distribution we find approximately 30% non-tasters, which is the usual percentage. (see fig.13)

This difficulty seems to illustrate the uncertainty of

Fig. 13. Total distribution of PTC taste thresholds (data from Table F12).



presenting PTC tasting in terms of two classes. Though it is convenient to use a twofold division in presenting reaults it must be remembered that it is the shape of the distribution as a whole that characterizes the population. In this case it may also be significant that none of the previous samples were of Midland origin, and that the Harris and Kalmus sample was of persons in the London area. It is possible therefore that there are regional differences in PTC tasting ability. Certainly Sunderland (1966) has reported British groups with non-tasters frequencies varying from 23.8% (N.W. Northumberland) to 37.7% in the Orkneys. In Partridge's study of the Black Mountain area he found that of those children with both parents born locally, 44% were non-tasters, while another group of children who had one local and one non-local parent had only 17.53% non-tasters. Though some of these extreme results may be due to small sample sizes it would appear that there is evidence of regional variation in this characteristic. However the results of the parental birthplace divisions of the present survey give some indication of regional variation, though the picture is not clear. When the antimode is set between solutions 3 and 4 there is a difference of 3.6% between the percentage of non-tasters in the English and British groups. With the dividing line at 6/7 the percentage difference rises to 5.4%. In the female sample the largest difference is between the Midland group and the English group. In the 3/4 division there was a difference of 5.6% in the percentage of non-tasters in these two groups, while in the 6/7 division the difference was 6.8%. While these differences are not significant overall they may represent basic regional differences, but it is also possible that the smaller size of the British and English samples is responsible for this apparent variation. (see 3P.2)

5P.3 Sex Differences in PTC Tasting

Some surveys of PTC tasting have reported a sex difference in tasting ability, with females in general having a greater taste sensitivity. However other reports from similar populations have not shown any sex difference, and the situation is not clear. In 1937 Boyd and Boyd noted sex differences in several populations and Hartmann (1939) found slightly more female tasters. Falconer (1947) found that females had a lower taste threshold and Harris and Kalmus (1949) found that the antimode in their female group was one dilution below that of the males. Boyd (1951) notes that a sex difference is found, and Mohr (1951) confirms this. A significant sex difference was found by Merton (1958) in a Norwegian population. Sheba and co-workers (1962) noted a significant sex difference in an African Jewish population, with females having a higher taste threshold, and Saldanha (1962b) found a slight difference in a Brazilian population. In Israeli groups Brand (1963, 1964) found sex differences in a sample suffering from poliomyelitis and their controls, but not in a goiterous group or their control group. There was an increased frequency of male non-tasters in the polio group and a slight increase in female non-tasters in the goitre group. Sex differences in Indian tribes have been noted by Das and co-workers (1963) and by Das and Mukhergee (1964). Montenegro (1964) found that among the Tucano Indians the proportion of non-taster males greatly exceeded that of non-taster females, while Giles and co-workers found a similar situation in a Mexican group. Romanus (1965) examined a group of Swedish females and found a significant difference between the proportion of tasters in nulliparae and multiparae. In a group of Derbyshire schoolchildren Cartwright and Sunderland (1967) found a significant sex difference, with 8.4% more non-tasters in the female sample. A sex difference in taste sensitivity has also been reported for PROP, a substance allied to PTC (Kaplan et al 1964a, see section 5P.7).

In contrast to these reports Cohen and Ogden (1949) stated that there was no sex difference in PTC tasting. Akesson (1959ab) found that there was no sex difference among Swedish students. Freire-Maia and Quelce-Salgado (1960a) found that there was no sex difference in a group of Russian immigrants to Brazil, while Saldanha and Naevur (1963) found no sex difference in Chileans. In a British population Pullin and Sunderland (1963) found that a group of schoolchildren lacked any sex difference for this trait.

The results of the present survey show no significant sex difference, with a difference of only 0.3% between the proportions of non-tasters in the male and female groups for the 3/4 division, and only 0.1% between the groups in the 6/7 division. It is difficult to suggest what factors can give rise to a definite sex difference in some samples but not in others. Though there may be racial factors involved it has been shown that two British samples may differ in this respect. (Pullin and Sunderland 1963, Cartwright and Sunderland 1967). Since these two samples were comparable for factors of age and type of subject, and the same methods were used in each case it would appear that the variation in this character may be regional within the British Isles.

Kalmus and Trotter (1962) have shown that there is a gradual decrease in taste sensitivity with age, so it is possible that some apparent sex differences could be due to age differences in single sex samples. It is also possible that a sex difference might appear in an adult sample but not be present in an adolescent sample owing to changes at puberty. Le Magnan (1948) has shown that the ability to smell the compound exaltolide is present only in mature females. However it must be boted that Cartwright and Sunderland's group, who showed a definite sex difference, were also schoolchildren, and so this theory cannot provide an explanation. (see 3P.2)

5P.4 Association of PTC Tasting and Disease Susceptibility

Reports of associations of PTC tasting and various diseases may be classified into two groups; those conditions with some association with thyroid activity and those without. It is proposed to discuss the latter group in the present section, and the former group in the next section. A wide range of conditions have been tested for possible association with PTC tasting ability possibly because of the availability of hospital patients as experimental subjects. However in many cases there are conflicting reports from different sources.

Terry and Segal (1947) found an increased proportion of non-tasters among diabetics, but Akesson (1959) failed to find this relationship. Saldanha (1956) found a decreased frequency of non-tasters among patients with tuberculosis, and an increased frequency of non-tasters among tuberculous children. The result for adults was confirmed by Beiguelman (1964c) who also found a reduced non-taster frequency. But Akesson (1959) had been unable to demonstrate any difference between tuberculous and normal groups in taste ability.

Manlapas and co-workers (1965) found an increased percentage of non-tasters among children suffering from cystic fibrosis. This condition is known to affect taste sensitivity in general, though the general effect is to lower taste thresholds for substances such as sucrose, hydrochloric acid, sodium chloridem sodium bicarbonate and urea (Henkin and Powell 1962). It seems likely that in this case the taste difference is the effect of the cystic fibrosis.

An association of taste sensitivity for PROP and duodenal ulcer was noted by Kaplan and his co-workers in 1963. The duodenal ulcer group were significantly different from both the normal control group and another group of gastric ulcer patients. Development of a duodenal ulcer has been shown to be associated with blood group O so it is perhaps unexpected that Haro (1963) found an association between blood group O and the non-taster class. In Haro's sample 71.4% of the non-tasters were group O as compared with 50% of the total sample.

Beiguelman (1964ab) and Beiguelman and Marques (1964) found a decreased frequency of non-tasters in leprosy patients and in patients with both tuberculosis and leprosy. There was however no association between PTC taste ability and the efficiency of the treatment of the patients' leprosy. Bradn (1964) found an increased frequency of non-tasters among victims of poliomyelitis and concluded that the non-tasters genotype may be more susceptible to the poliomyelitis virus.

Milunicova et al (1969) found an increased frequency of female tasters with genital cancer and increased frequency of non-tasters among glaucoma patients was noted by Becker and Morton in 1964). Chung and co-workers (1964) found an association between dental caries and low taste sensitivity for PTC. The parents of a group of mongol children were reported to have a low taste sensitivity for PROP when tested by Fischer and co-workers in 1963).

5P.5 Association of PTC Taste Sensitivity and Thyroid Function

PTC is known to be a goitrogen and so a comparatively large number of surveys have investigated the possibility of association between taste sensitivity and various aspects of thyroid malfunction. Kitchin and co-workers (1959) noted increased frequencies of non-tasters in patients with adenomatous goitre, and an increased frequency of tasters among those with toxic diffuse goitre. Shephard and Gartler (1960) found an increased frequency of non-tasters not only among a group of athyreotic cretins, but also among their mothers, fathers and normal sibs. They suggested that the non-tasters foetus is more susceptible to thyroid damage by maternal chemicals. Fraser (1961) also found a higher than average percentage of non-tasters among cretins and their parents. Brand (1963) found that the frequency of non-tasters in a group of goitre patients was approximately four times the normal frequency, but Covarrubias (1965) did not detect any taste acuity difference in a comparison of goitre and normals, nor did Fraser (1963) detect any variation from the normal proportions in a sample of patients with nodular goitre.

In a more biochemically based survey Widstrom and Henschen (1963) noted that there were differences in taster frequencies in groups with different levels of protein-based iodine (PBI) in their serum. It was found that there were more tasters in the group with high PBI and a less than average number of tasters in the low PBI group. Thus PTC tasting appears to be associated with thyroid metabolism. Another possible effect of difference in thyroid activity was shown to be associated with PTC tasting by Johnson and co-workers (1966). They found that among Negro children the tasters were taller than the non-tasters and concluded that both factors could be associated.

Price-Evans and fellow workers (1962) investigated the metabolism of thiopentone and methyl thiouracil in tasters and non-tasters of PTC. Both these compounds have the same bimodal distribution of taste thresholds as PTC, but there was no significant difference between tasters and non-tasters with regard to the metabolism of the compounds. Nis wander et al (1963) tested the possible association between the most anodally migrating salivary component in electro-pheresis and PTC tasting. They obtained a positive but non significant correlation between the two factors, with a correlation coefficient of 0.18, and concluded that the two factors were probably independent.

It has been found that many common foodstuffs contain large amounts of goitrogenic substances. Greer and Astwood (1948) found that vegetables were more active than animal foods, though beef, liver and oysters had some activity. Among vegetables turnips, pears and strawberries were particularly active. Greer (1957, 1962) notes the difficulty of assessing the effects of the foods in producing goitre, as only turnips contain a concentration of goitrogen large enough to be effective in man. However he states that in some circumstances ingestions of large quantities of goitrogenic foods could contribute to this condition. It is possible that goitrogens may be present in milk by transference from the foodstuffs of the dairy herd, but this relationship has not been definitely established (Clements and Wishart, 1956) (Green and Farran, 1958).

In view of the presence of these potentially toxic goitrogens in foodstuffs it is interesting to note that the antithyroid factor of the turnip shows the same distribution of taste thresholds as does PTC (Boyd 1950). This antithyroid factor, L-5-vinyl-thiooxazolidone, was found to be as active a goitrogen as 6-n-propylthiouracil (PROP) (Astwood et al 1949). Motulsky (1963) has suggested that the ability to taste PTC and other goitrogens in food might be a selective factor, and Workman and co-workers (1963) have noted that the population differences in PTC threshold distribution are so great that the characteristic must have some adaptive function.

They put forward the view that this could be an unstable polymorphism, and Price (1967) suggests that non-tasters may avoid goitrogenic substances because of their ability to taste them.

5P.6. Factors affecting taste sensitivity

It has been found that certain diseases bring about associated changes in taste sensitivity, as mentioned in section 5P.4 with regard to cystic fibrosis. Adrenal cortical insufficiency has been found to increase the patients' taste sensitivity a hundredfold (Henkin et al 1963). Taste response to a particular substance can also be altered by adapting the subject's oral environment to that substance (McBurney and Pfaffman 1963). Thiol-containing drugs tend to decrease taste acuity in man, whereas copper and zinc will return this taste acuity to normal (Henkin and Bradley 1969). As previously stated in the twin section (4D.14) taste acuity in women may be affected by the stage of the menstrual cycle (Elsberg et al 1935). Cohen and Ogden (1949b) showed that it was necessary for the subject's own saliva to be available for the PTC taste response to be shown.

Other workers have shown that certain taste modifying substances exist. Warren and Pfaffman (1959) found that the leaves of Gynema sylvestre contained a substance that suppressed sweet tastes. Another substance extracted from the 'Miracle Fruit' (Richardella dulcifica) has the effect of modifying taste reception such that sour tastes sweet (Kurihara and Beidler 1961, 1968, Brouwer et al 1968). Kurihara and Beidler (1961) suggest that the substance in the form of protein molecules becomes bound to the surface of the taste cells. When acid is applied the surface of the receptor membrane is changed such that the sugar residues of the protein fit the sweet receptor site.

5P.7. Taste testing with 6-n-propylthiouracil (PROP)

In America extensive work on taste testing has been carried out under the leadership of Professors R.Fischer and F. Griffin. This team use a modification of the Harris and Kalmus technique, using 6-n-propylthiouracil instead of phenylthiocarbamide. White it seems probable that the same polymorphic factor controls taste sensitivity for PTC and for PROP it is not certain that the results are wholly comparable. In this case it has been decided to report PROP results in a separate section, except where there is a direct relevance to a section concerned with PTC.

In 1959 Fischer and Griffin noted that the distribution of saliva iodine (total PBI) was similar to that of the PTC distribution.

Although they had not tested the two factors in the same group of subjects they concluded that there was a genetic association between taste sensitivity and the activity of the enzyme system tyrosine iodinase. They suggested that PTC and related compounds were specific inhibitors for this system. Differences in the reactions of taster and non-taster salivas with PROP were shown by Griffin and Discher in 1960.

Having assumed that taste accuity for PROP was controlled by the thyroid hormones, Fischer and Griffin (1961) showed that mono-and/di-iodotyrosine could lower the taste threshold of their subjects. They also suggest that there is a taste dimorphism for quinine, which is not however associated with the PTC taste dimorphism. Thus it is possible in theory to sort out four groups: those with high PTC and quinine sensitivities; high PTC and low quinine; low PTC and high quinine and low sensitivity for both compounds. In this case there was no separation of the PTC taster group. The authors also report that migraine sufferers tended to be non-tasters of PTC and quinine.

Association of PROP tasting and food preference was investigated by Fischer and co-workers in 1961. There were some differences between those liking most foods and those disliking most foods on a list. In a further study of the complexities of the taste reaction Rubin and co-workers (1962) found that mixtures of PTC and quinine produced a bitter taste at concentrations below the threshold for either substance. Fischer and Griffin (1963) then reaffirmed their view that PROP thresholds should be modified by reference to the subject's quinine threshold, quinine tasting being bimodal. Fischer et al (1963ab) also discussed the use of quinine in PROP taste tests.

The effects of age on PROP taste sensitivity were noted by Glanville and co-workers (1964). They found that there was an increase in sensitivity from ages 16 to 20, followed by a gradual decline. The rate of decline of taste sensitivity was found to be faster in males than females for both PROP and quinine.

An association between tasting ability and the digital symbol score of the Wechsler Adult Intelligence Scale was reported by Fischer and Griffin (1964). Although only 27 subjects were used a correlation coefficient of 0.4 was noted. In this paper the authors mention the possibility of fluctuation in the taste threshold of an individual from day to day. They suggest that this variation could be as great as one dilution. They also confirm that an individual can only taste PROP in his own saliva. Even when a concentration of PROP higher than the individual's threshold is dissolved in another subject's saliva, it cannot be tasted by the individual. This parallels the results of Cohen and Ogden (1949b) for PTC.

The effect of the menstrual cycle and PROP tasting ability was discussed by Glanville and Kaplan (1965acb). They tested a number of nurses 3 times weekly for 4 to 9 weeks, covering 1 or 2 menstrual cycles. Many of the girls showed an increase in taste sensitivity during the menstrual period.

In a further survey of food preference and taste sensitivity, Glanville and Kaplan (1965c) found a positive correlation between a likeing for strong tasting food and insensitivity to PROP and quinine. A previous study (Kaplan and Glanville (1964) had shown a decreased taste sensitivity among heavy smokers. It is probable that these results represent the effects of food and smoking behaviour upon the taste receptors, rather than any genetic differences.

5P.8 Consistency of PTC Taste Results

Harris and Kalmus (1949) resported good repeatability of taste thresholds when the same subjects were tested on two occasions separated by several weeks. However Soltan and Bracken (1958) and Hoover (1956) found that a certain proportion of individuals varied in their response to PTC paper when they were examined a number of times. Skude (1960a) retested a number of subjects 6 to 15 times, and found that their taste thresholds varied by up to 4 dilutions over a period of time. This variation over time was also noted by Freire-Maia and Quelce-Salgardo (1960b) while Guttman and co-workers (1965) found that many subjects changed between taster and non-taster on retesting. Skude (1959, 1960b) noted that some subjects found PTC to taste sweet instead of bitter.

In view of these results it would seem that the taste threshold of an individual for PTC cannot be defined as a fixed point. It is probable that there is a potential range of taste sensitivity for each individual. Any single determination of taste sensitivity will show a threshold with the personal range of the subject. Even though all the members of a sample may show a similar day to day variation in tasting ability, this does not invalidate any comparisons between groups. It is unlikely that the direction of the variation is influenced by outside factors, and it is therefore probable that the variations would occur randomly in both directions. Thus there would be little change in the overall shape of the distribution of taste thresholds for the population.

It was hoped to make a full study of variation in taste thresholds for PTC by arranging for repeated trials with a number of subjects. But this project was abandoned owing to concern about the potential toxic effects of PTC on the subjects. The possible toxicity of PTC is discussed fully in a later section (see section 5P.15).

One possible explanation of the variations in PTC taste accuity is that it is affected by the stage of the menstrual cycle. This relationship could only hold in women, and so there must be other factors involved in taste variation. Conversely it is possible that the apparent menstrual variation reported by Glanville and Kaplan (165ab) is in fact normal day to day variation. It is perhaps significant that Beiguelman (1964) found no association between the stage of the menstrual cycle and taste ability.

5P.9 PTC Tasting and the Effects of Smoking

Many of the adult (student) subjects in the pilot survey and a few of the main survey children commented that their smoking habits might affect their taste reactions. In fact the literature is divided on this point. Falconer (1947), Akesson (1959) and Freire-Maia (1960) found no difference in taste accuity in the smoker and non-smoker groups. Though Krut and co-workers (1961) found no significant difference in taste they were of the opinion that the addiction to nicotine could produce taste difference effects. An earlier study by Hall and Blakeslee (1945) had shown a confused picture. Subjects were tested before and after smoking. Of these 73.3% had a decreased taste ability on the second tasting, but 20.0% had increased ability. The remaining 6.6% showed no change. Kaplan and Glanville (1964), using PROP, found a significant difference between heavy smokers and non-smokers.

In general it would seem that the effects of smoking are not particularly important in determining PTC taste thresholds. Though there may be an immediate effect just after smoking, the long term differences are not large. It was decided not to ask the subjects to state whether or not they were smokers. In the case of the pilot survey the sample size was too small to allow for any useful information to be gained by this question. Since the main survey was being conducted in school time it was thought unlikely that many subjects would have been smoking during the time preceding their interview. There was also little likelihood of honest responses being obtained had questions on smoking been included. It is also possible that those children who mentioned smoking were in fact merely boasting.

5P.10 Association of PTC Tasting and Social Class

The difference in PTC taste threshold distribution between the two school types were comparactively slight, amounting to 3.1% among the males and 2.7% in the females when the 6/7 division is used, with a higher proportion of non-tasters in non-selective schools. When the 3/4 division is used the differences are reduced, and in the males the trend is reversed. There were 3.2% more non-tasters in the male selective sample than the non-selective sample, but among the females the percentage difference was only 1.5%. These differences are probably due to sampling variation rather than any biological differences in the groups, but it is possible that the association of PTC tasting and social class is reflected here.

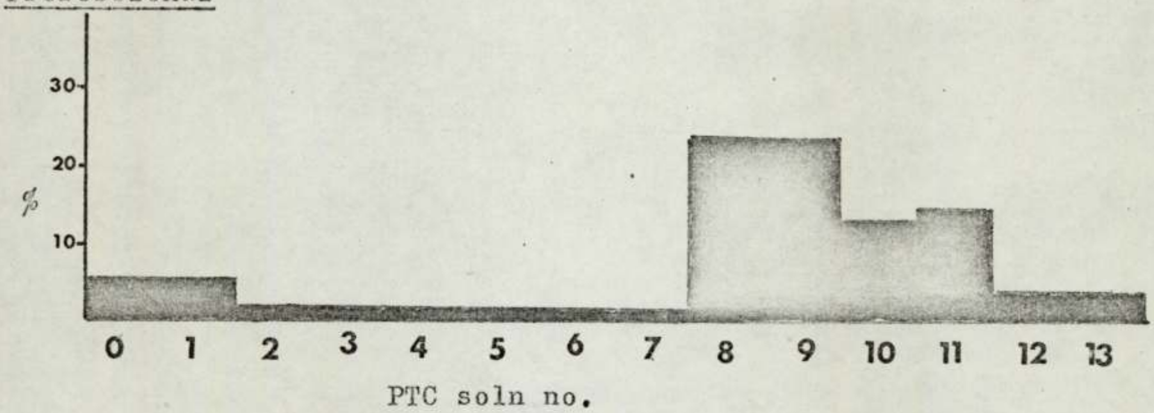
Though significant associations of social class and PTC tasting were found in both sexes the situation is far from simple. There is no simple relationship between social status and taste ability, and the trends in the two sexes seem opposed. With the 3/4 division it was found that the percentage of non-tasters in the middle class male group exceeded that of the professional group by 9.4% and the manual group by 10.9.. When the distribution is divided at 6/7, the difference between the middle class and manual groups is narrowed to 1.9%, but the professional/middle class difference is increased to 11.9%. From this it would seem that in males the three groups could be arranged in order of increasing taste accuity with the middle class lowest, manual group intermediate and professional group highest.

However among the females the middle class group showed the greatest taste accuity, though the differences were less noticeable than those in the male samples. The percentage of 3/4 non-tasters in the female middle class group was exceeded by 5.0% by the professional group and 5.4% by the manual group. But when the 6/7 division is used the proportions of non-tasters in the manual group rises to overtake the professional group. The professional group again exceeds the middle class group by 5%, but the manual group difference now rises to 10.3%. The order of taste accuity in the female sample would seem to be manual group lowest, professional group intermediate and middle class highest. (see fig.14)

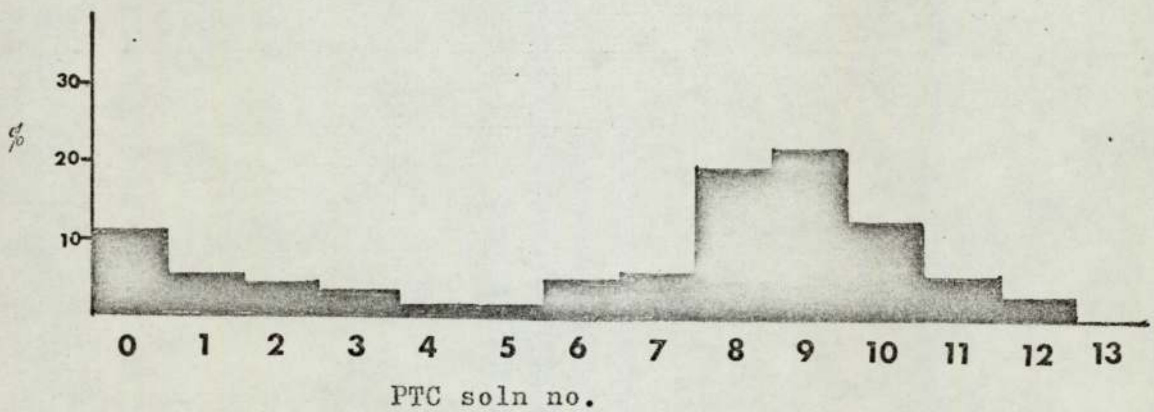
No previous study has investigated the possibility of an association between taste accuity and social class, so there are no previous results for comparison. It is accepted that the manual and professional class groups are somewhat reduced in numbers in comparison with the middle class, but they still represent a substantial sample, and though sample size may account for some of the variation it is unlikely to be responsible for the more extreme differences. Since the social class group differences are far greater than the parental background differences it is unlikely that any uneven distribution of backgrounds has given rise to the present situation. It must be concluded that there are real variations in the PTC taste threshold

Fig. 14a. PTC taste threshold distribution by class group in male UK sample (data from Table F.12).

Professional



Middle



Manual

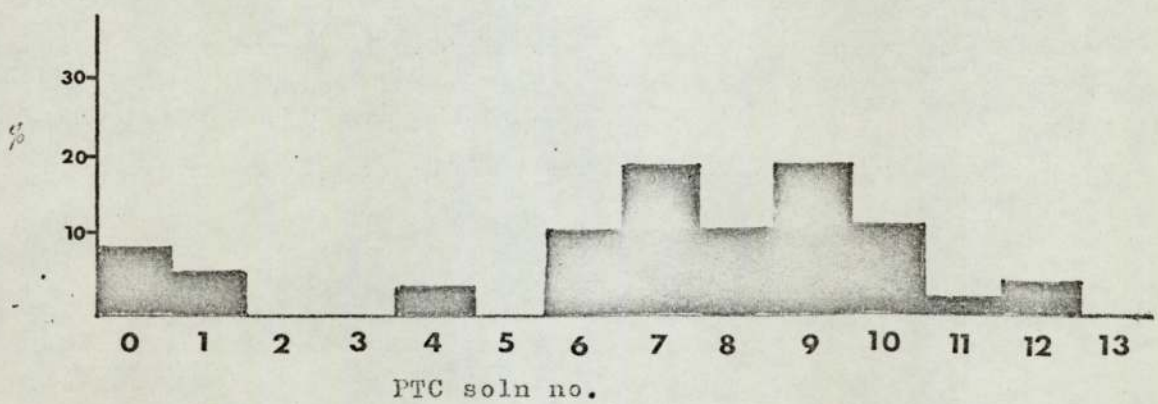
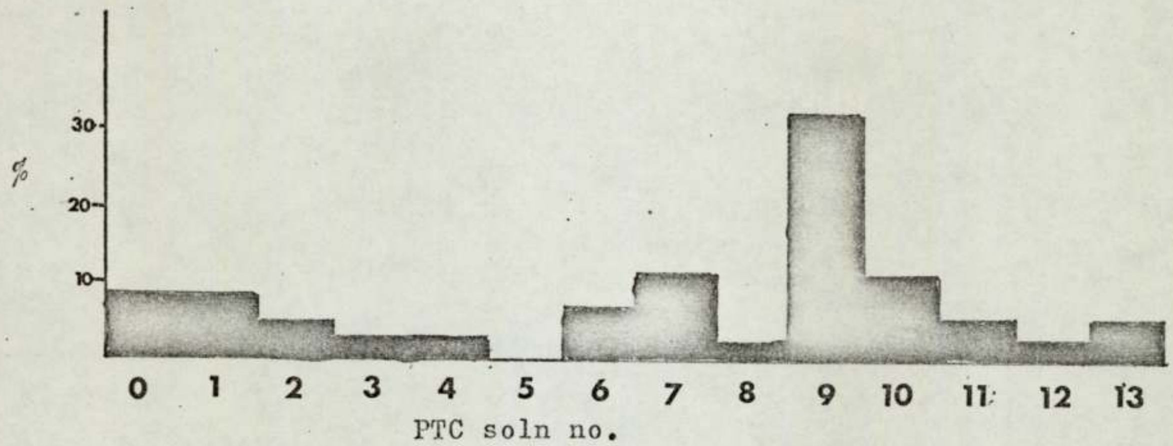


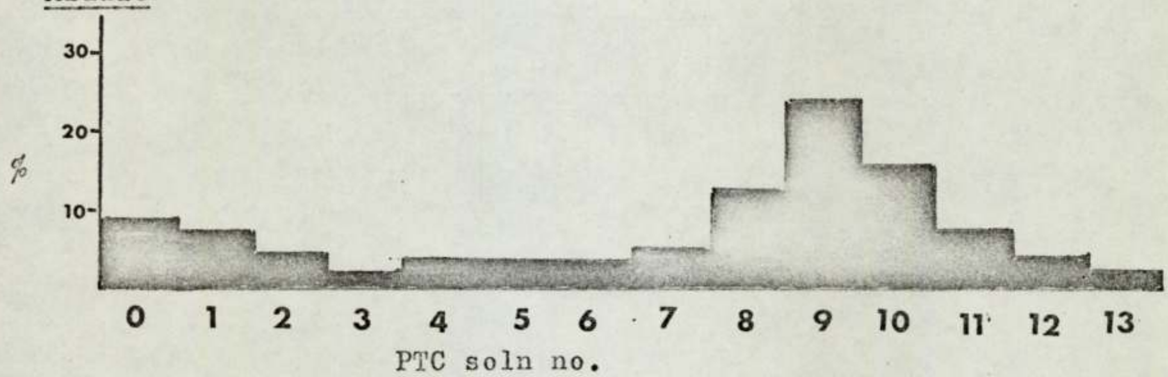
Fig. 14b. PTC taste threshold distribution by class group (data from Table F.12).

Female

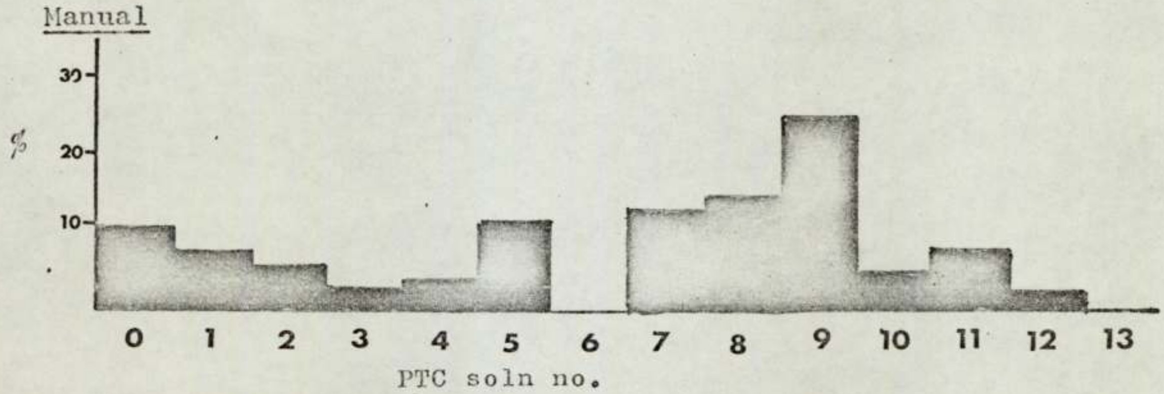
Professional



Middle



Manual



distribution in the different social class groups.

In view of the difference in the results of the sexes it must be remembered that a number of workers have reported sex differences in their data (see Section 5P.3). Though in this case the overall frequencies of non-tasters in the two sexes were almost identical, it is possible that sex influenced factors were also present. If there were sex influenced modifying factors affecting this trait, this might account for the inconsistency of the reports of sex differences. (see 3P.2)

5P.11 Association of PTC Tasting and Skin Type

It was found that in the male sample increased freckling appeared to be associated with an increase in taste accuity. This relationship was not present among the females. Though neither PTC tasting nor skin type were found to show significant sex differences, it had been noted that several previous characteristics show association with skin type in the male sample alone. Since skin type is significantly associated with parental origin, it is possible that the present association represents geographical variation in PTC tasting. This is unlikely to be the sole cause of the variation as it has been shown that PTC tasting is not significantly associated with parental origin. It may be that there is a complex of sex influenced factors affecting skin type and height, weight, foot length as well as PTC tasting. This association has not been noted in previous surveys. (see 3P.2)

5P.11 Association of PTC Tasting and Mid-digital Hair

Though significant associations of PTC taste threshold and MDH type were present in both sexes the relationship was not a simple one. It might have been expected that some direct or inverse relationship between the two variables could be found, but in fact the results indicate that in certain MDH types the whole shape of the PTC taste distribution differs from the average type. Nor were these deviations parallel in the two single sex samples. In the males the most notable differences were a deficit of non-tasters in the MDH 2 group while the MDH 3 group contained excess non-tasters. But the female MDH 3 group contained a deficit of non-tasters.

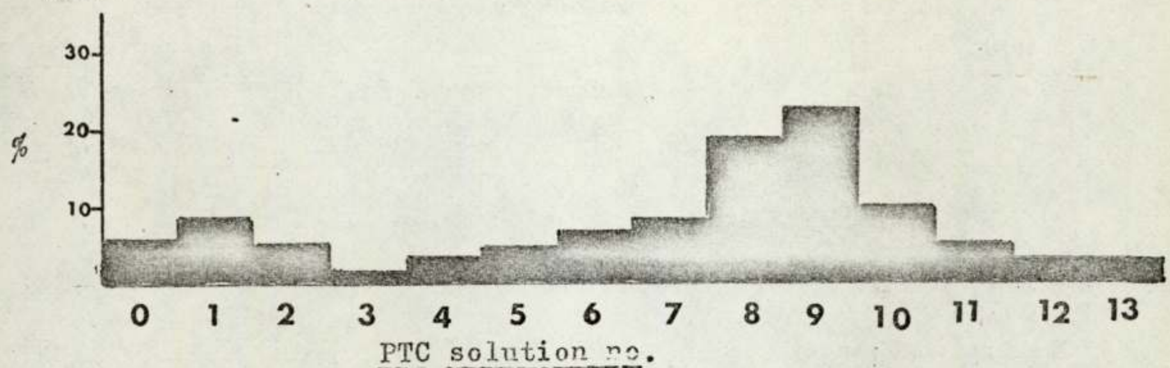
It is possible that the smaller size of the MDH 3 groups in each sample has led to this apparent variation, but both groups were large enough to give significance in the chisquare contingency tests. The appearance of significant differences in both sexes tends to confirm the validity of the association. The difference in the trends of the association in the two samples may be due to sex influenced factors. It may be significant that both PTC and MDH have been found by some authors to show the effects of sex influenced factors, though in the present survey neither trait showed any significant sex difference. No previous mention of an association between PTC and MDH has been found. (see 3P.4) (fig.15)

5P.13 Association of PTC and Hair Colour

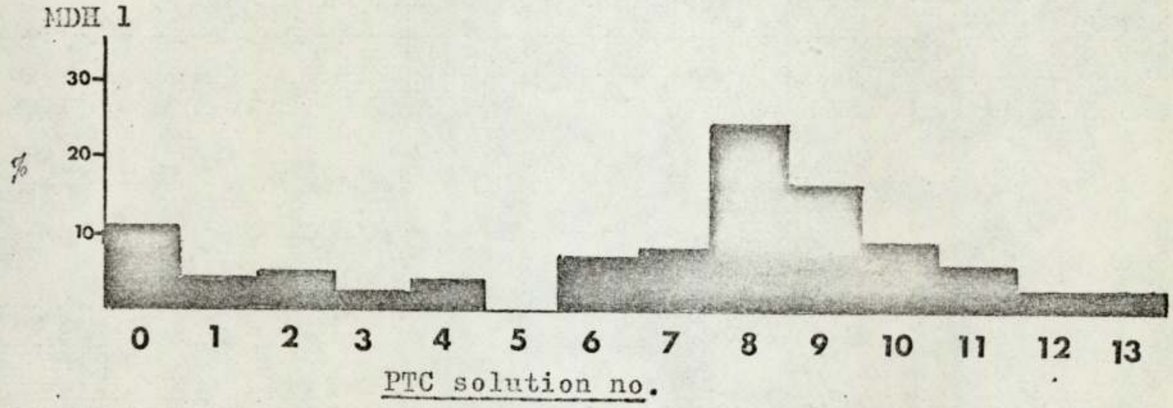
In fact the only significant association under this heading was between Munsell Chroma and PTC tasting. This relationship

Fig. 15a. PTC taste threshold distribution by mid-digital hair in male UK sample (data from Table I.19).

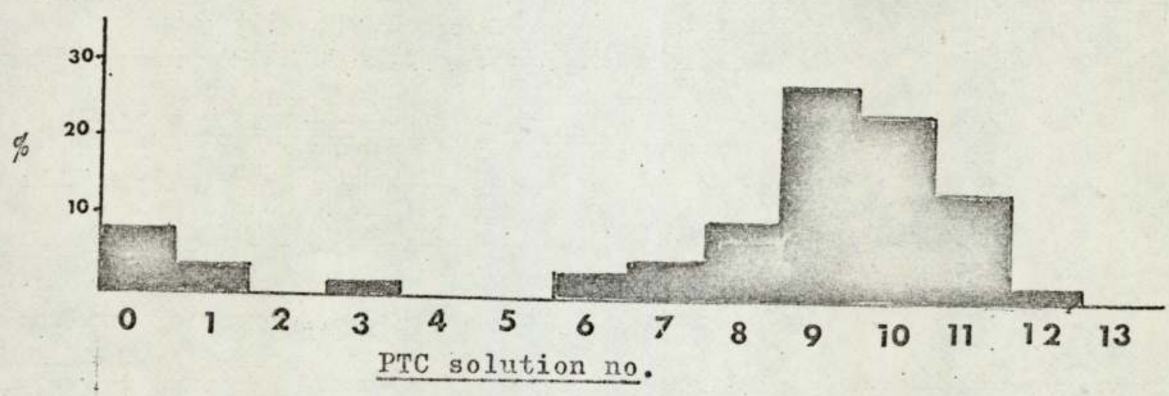
MDH 0



MDH 1



MDH 2



MDH 3+4

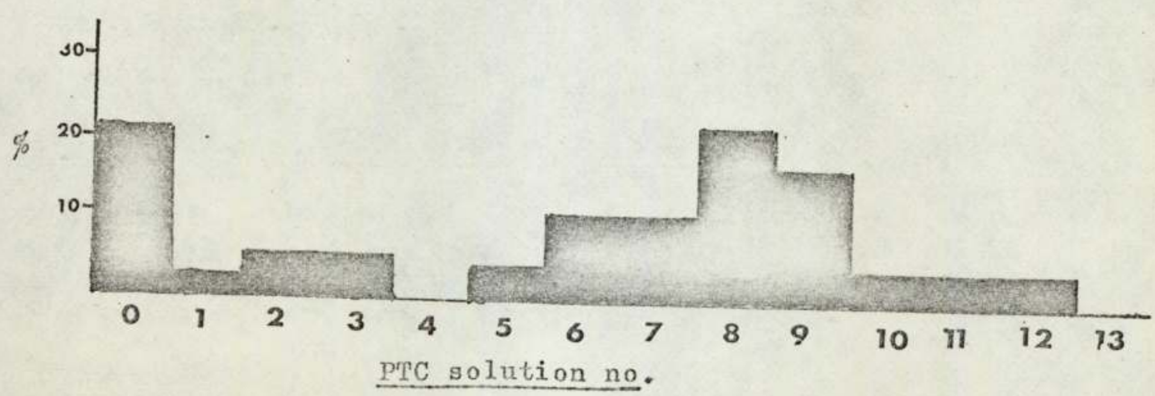
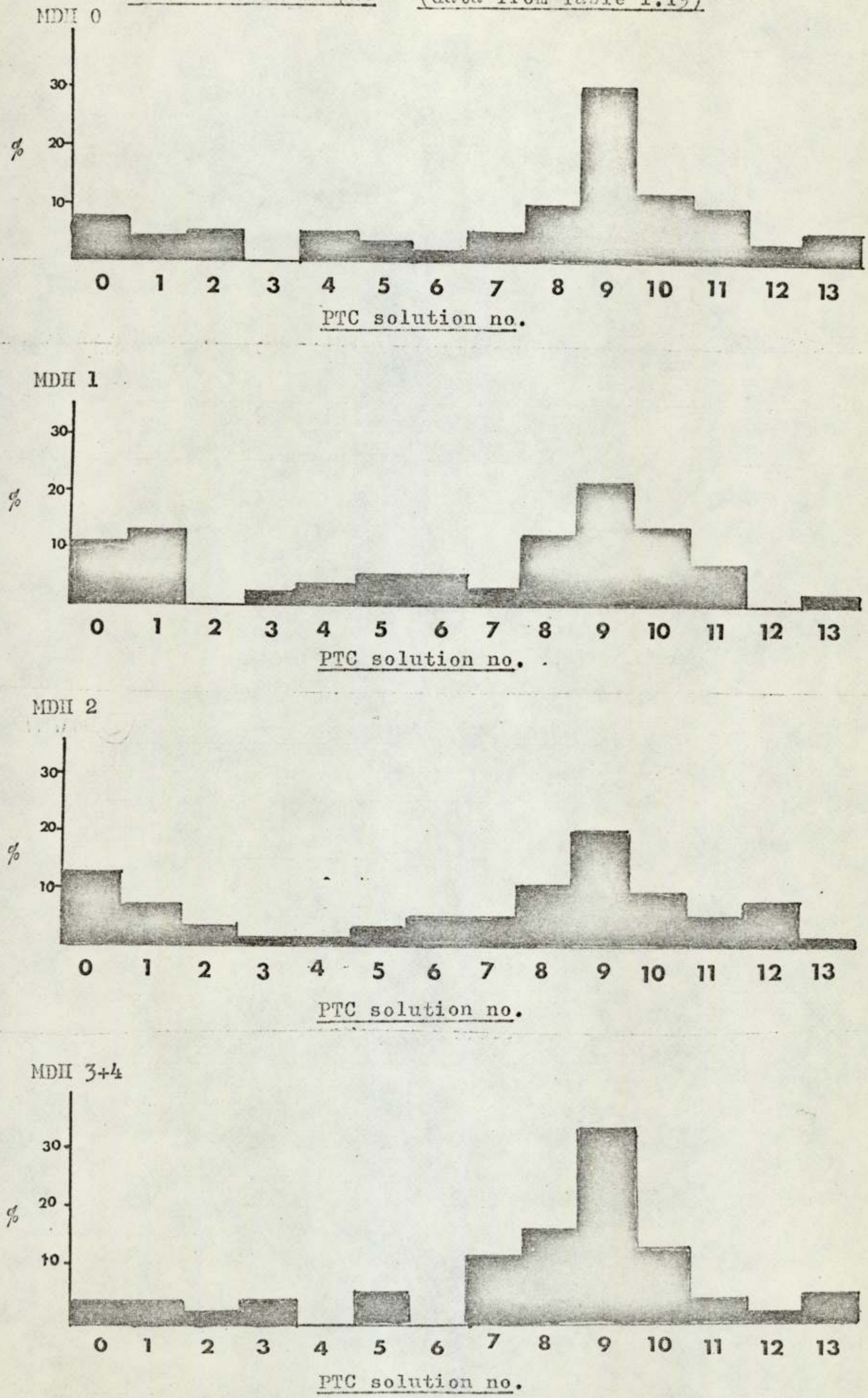


Fig. 15b. PTC taste threshold distribution by mid-digital hair in female UK sample (data from Table I.19)



was only found in the female sample. In general the hair of the non-taster females was more deeply pigmented than the hair of the tasters. The association was not present in the male sample, but this lack of significance could be the result of the sex differences in hair colour in the present survey, previously examined. Both PTC tasting and hair colour are traits which show some regional variation within the British Isles, and it might be that this association represents differences between regional types. However the lack of association of the more conventional hair colour classifications with PTC tasting would seem to undermine this argument. (see 3P.5)

5P.14 Association of PTC Tasting and Laterality

PTC tasting was significantly associated with only card dealing and needle threading of the ten laterality activities. In both cases there was an increased proportion of non-tasters among the left dominant subjects. It may be that the significant association of card dealing and needle threading has led to both being apparently associated with PTC when in fact only one activity shows this relationship. But in that case it would be expected that more of the laterality activities, which are closely interrelated, would show such an association.

Such an association between PTC and laterality has not previously been demonstrated, but the present situation seems clear. The lower totals in the left handed group of the single sex samples could be responsible for their apparent divergence from the right handed sample, but these sub-totals are adequate for statistical purposes. The fact that the trend is shown in both sexes adds strength to the validity of the association. (see 3P.6 & 3P.7)

5P.15 Potential Toxicity of PTC and Related Compounds

5P.15a Past Work of PTC Toxicity

It was previously noted (section 5P.8) that the idea of performing a series of taste determinations of the same individual had been discarded owing to anxiety as to the possible toxic results of such action. In view of the wide usage of PTC tasting at all levels of education it is necessary to support this view with reasonable indications that such a possibility exists.

In fact it was not until after the completion of the active survey work that a series of papers giving details of the toxicity of PTC in rats were first seen. In fact these reports (Richter and Clisby 1941, 1942, Richter and Campbell 1941) are seldom quoted in PTC literature.

In 1942 Richter and Clisby decided to investigate PTC tasting in rats. They fed PTC crystals to a small number of rats and were surprised to find that all the treated animals died within hours. Doses of 1 to 10 mg were fatal in 3-18 hours, the symptoms being pulmonary oedema and pleural effusion. There was also a marked decrease in body temperature. They suggest that the median lethal dose when administered by stomach tube is 1.0 mg. There was no correlation between the dosage, weight, method of drug administration and survival time. Up to 14 cc of fluid was present in the thoracic cavity of the affected rats. In a further investigation of the effects of PTC on rats Richter and Campbell (1941) established that the taste thresholds of rats had the same approximate range as humans. If rats were given PTC solution with 20% dextrose added to make it attractive 50% of the, drank a lethal dose. When PTC was mixed in their food in concentration of 0.1 to 0.5% 7 out of 9 rats ate a lethal dose, the amount of PTC taken in these cases ranging from 20 to 150 mg.

The effects of long term ingestion of PTC were also investigated by Richter and Clisby (1941, 1942). When sub-lethal doses of PTC are given over a period it is possible to build up tolerance in the rats. There were various effects, the most notable being the hyperplasia and hyperactivity of the thyroid gland, which then shows the characteristics found in exophthalmic goitre. There is atrophy of the thymus and ovaries and a decrease in body temperature and weight. In black rats a notable colour change is observed. Starting behind the ears the fur turns grey in a definite pattern which is completed within 58 days of the start of PTC treatment. The greying is reversed if PTC dosage is discontinued. Dieke et al (1947) estimated that the LD50 for PTC in rats was 3.1 mg/kg and Carroll and Noble (1949) found an LD100 of 5 mg/kg.

Richter and Clisby gave the following warning about the use of PTC in humans :

'The possible dangers involved in the use of PTC may have to be taken into account in genetic studies in which this substance is used on human beings. The amount used for a single taste threshold test is so small that the appearance of toxic effects would seem unlikely. In giving repeated tests over several weeks or months the toxic action should undoubtedly be considered' (1942).

Richter and Campbell warned of the danger as follows:

'Since about 5% of human beings scarcely taste the substance (PTC) or do not get its bitter taste at all, they very likely would take dangerously large amounts even if the phenylthiocarbamide were offered in acqueous solution' (1941).

PTC has been shown to be a very effective inhibitor of tyrosinase in vitro (Paschkis et al 1944, Bernheim and Bernheim 1942), but Bernheim and Bernheim (1942) do not think this effect accounts for the toxicity, though it might be responsible for the colour change in rats.

More recently is has been suggested that the toxic effects of PTC may result from desulphuration of the compound to liberate hydrogen sulphide at a tissue level. Scheline et al (1961) used ^{14}C and ^{35}S labelled PTC to demonstrate that the sulphur followed a different pathway from the remainder of the molecule. It has also been demonstrated that thiourea derivatives which do not readily liberate hydrogen sulphide are relatively non-toxic (Smith and Williams 1966) whereas intravenous or intraperitoneal injections of a~~c~~queous hydrogen sulphide were fatal within seconds (Smith and Williams 1961b). In rabbits the oral LD50 is 40 mg/kg for PTC, but the metabolic pathways in hens appears to differ with an LD50 of approximately 1000 mg/kg. (Scheline et al 1961).

In view of this high level of toxicity it was decided to calculate the maximum dose that could be received by human subjects during taste testing. This is difficult to define, as there is no limit to the volume of solutions used in the sorting test, and the cups may be refilled. (Harris and Kalmus 1949). However it was decided to work on a basis of 10 cc per mouthful, as a small scale survey of 8 subjects had an average mouthful size of 9.7 cc. Previous experience has shown that subjects tended to swallow the test solutions even when facilities for spitting were provided. The dosage of PTC per mouthful of each dilution was calculated, and from this the total maximum dosage was worked out (see fig.16). On the expectation that an extreme non-taster subject could consume 10 cc of each of 13 dilutions, plus 40 cc of each of the two most concentrated solutions, the total would be 104 mg of PTC. This gives a dose of approximately 2 mg/kg for a 50 kg subject and 1.5 mg/kg for a 70 kg subject. These dose levels appear undesirably close to the toxic level in rats previously quoted.

5P.15b Development of Commercial Rat Poison

Following the discovery of the toxicity of PTC to rats work began on developing this property as a commercial rat poison. Richter (1945) noted that some rats would not take PTC though it was

Fig. 16

Maximum concentrations of PTC consumed by an extreme non-taster

Concentrations of PTC in Harris and Kalmus solutions.

Soln. No:	mg per 1000cc	mg per 10cc	mg per 40cc
1.	1300.00	13.000	52.000
2.	650.00	6.500	26.000
3.	325.00	3.250	13.000
4.	162.50	1.625	6.500
5.	81.25	0.813	3.250
6.	40.63	0.406	1.625
7.	20.31	0.203	0.813
8.	10.16	0.102	0.406
9.	5.08	0.051	0.203
10.	2.54	0.025	0.102
11.	1.27	0.013	0.051
12.	0.63	0.006	0.025
13.	0.32	0.003	0.01

Total consumption of a subject with taste threshold soln 1:

10cc of each of solutions 13 - 1	= 26.0 mg
40cc of solution No. 2	= 26.0 mg
40cc of solution No. 1	= 52.0 mg
Total:	= 104.0 mg

as potent a killer as strychnine to those that did. All the mono-substituted thioureas gave the same acute effects of pulmonary oedema with eventual death from a form of drowning. It was suggested that the effect of the drug was to produce greater permeability of the lung capilliaries. Lymph flow in affected animals was up to 80 times normal, and there was no antidote. There was no corresponding increase in lung size to account for the increased flow (Rodgers 1946).

The most effective thiourea derivative was found to be alpha-naphthyl-thiourea (ANTU). This compound had an LD50 of 7 mg per kg for brown (Norway) rats, though black rats were resistant. Dogs were also sensitive to ANTU being killed by doses less than 100 mg per kg, but many dogs were protected by vomiting. Richter suggests that ANTU may have an emetic effect. (It is possibly of interest that the only reported ill-effects of PTC tasting in humans was vomiting in two members of a family (Hutt 1947).)

Dubois et al (1946) found that 3 mg/kg was the LD50 for rats and 10 mg/kg gave 100% deaths. They found that after administration of ANTU there was an initial hyperglycaemia followed by hypoglycaemia. They noted that the deposition of glycogen in the liver was halted by ANTU, but could not explain the lung damage. Rats could be protected by dosage with cysteine, but this reaction did not occur in dogs (Byerrum 1946). Dieke and Richter (1946) noted that brown rats, mice and dogs were most sensitive to ANTU, being killed by less than 100 mg/kg, black rats, guinea pigs and cats needed 700 mg/kg to kill them, and monkeys and chickens were comparatively resistant to the substance. The LD50 in monkeys was 175 mg/kg for injections of ANTU and 4250 mg/kg for ingestion by stomach tube. The pulmonary oedema reaction was only found in brown rats, dogs, mice and cats. Emler (1947) noted that some dogs were acidentally killed in a rat control program by taking as little as 50 mg/kg of ANTU, but cats, chickens, rabbits and roof rats were resistant. No fatal case of ANTU poison in humans has been reported (Brewer and Haggerty 1958). In cases of accidental ingestion stomach washing was suggested. In fact ANTU has now been withdrawn from use by the Ministry of Agriculture owing to its carcinogenic effects. However the active agent in this case was thought to be free alpha-naphthylamine impurities in the ANTU rather than the thiourea. Professor Case of the Chester Beatty Cancer Research Institute confirmed by telephone that PTC is not considered to be carcinogenic.

5P.15c Toxicity of Thiourea and Thiouracil

Though there is comparatively little data about the toxicity of PTC itself, the early medical use of thiourea and thiouracil in control of hyperactivity of the thyroid gave rise to a number of reports on these substances. In consideration of the effects of thiouracil it is of interest that a group of American workers have made extensive use of 6-n.propyl-thiouracil (PROP) instead of PTC in modified Harris and Kalmus technique and it therefore seems relevant to include data on this compound.

In rats thiourea has the same fatal effects as PTC and ANTU. There are age differences in the effects, adult rats being more liable to acute effects and immature rats showing effects of thyroid enlargement and decrease in the basal metabolic rate (Mackenzie and Mackenzie 1943). It is also interesting to note that thyroidectomized rats also show the toxic pulmonary effects of poisoning with thiourea. Greisbach and co-workers (1944) found that the susceptibility of their rats to thiourea varied according to the strain, but they also mention a possible connection between the toxic effects in rats and in patients being treated with thiourea. Oedema of legs and eyelids, watering of the eyes and skin rashes were associated with thiourea treatment in humans.

Daft et al (1946) found that thiourea dosage produced anaemia and leucopenia in rats. There were lesions in the bone marrow, spleen and thyroid, with haemorrhage and necrosis of the adrenals. These effects were produced by adding 1% of thiourea to the diet. Leathem (1946) found that 0.5% of thiourea in rats' diet produced significant hypertrophy and seminal vesicle loss, within 20 days, though there was no evidence of damage to the pituitry, testes, kidneys or liver. Kennedy (1942) found that allylthiourea gave hypertrophy and hyperplasia of the thyroid in rats but there was no toxic effect. The addition of 1% proplythiourea to the diet of mice results in loss of body weight in treated animals.

As with ANTU, chickens were resistant to the effects of thiouracil, but feeding of 0.5% solutions over a period of 5 weeks gave deformities of the leg bones, retarded growth, scaly feet and a lack of black feathers. (Briggs and Lillie, 1946). In an experiment on the fattening of swine, Muhrer and Hogan (1945) included

0.2% thiouracil in the diet. The treated swine gained more weight than the control pigs but their growth was in fact retarded, and the rapid weight gain was due to excessive fat deposition. The pigs were shorter in both height and length than the controls, but wider. There was also behavioural change, the treated pigs spending most of their time asleep. The workers concluded that the flesh of the treated pigs might not be fit for human consumption.

A study of the distribution of thiouracil in patients who had been given the substance for seven days prior to their deaths was carried out by Williams et al (1944). They found that thiouracil was concentrated in the white blood cells, bone marrow, thyroid, ovaries and pituitary. Thiouracil is rapidly absorbed from the gastro-intestinal tract and it is excreted in urine. A daily dose of 0.2 to 1.2 g gave blood thiouracil levels of 0.8 - 6.4 mg.

Various effects of the use of thiouracil and thiourea on goitre have been noted. Gargill and Lesses (1945) found that 8 out of 43 patients had toxic reactions to their treatment. Of these eight, one developed fatal agranulocytosis, one had non-fatal granulocytopenia, 2 had jaundice, 2 had drug fever with splenomegaly and monocytosis, and 2 had sub-maxillary salivary gland swelling. The fatal case had received three courses of treatment for goitre in a year, but there had been periods without treatment within the year. Her average doses during the treatment periods was 0.2g of thiouracel per day. At the post mortem it was found that there was granulocytic hypoplasia of the bone marrow, and among other findings was the presence of fluid in the peritoneal and pleural cavities, though lung oedema was not present. In the non-fatal granulopenia case the patient developed a form of dermatitis at the same time. Gargill and Lesses warn that thiouracil is 'an unpredictably toxic drug which may produce serious and uncontrollable effects, especially on the bone marrow and liver'.

Another fatal case of agranulocytosis resulting from thiouracil treatment was reported by Khan and Stock (1944). In this case the patient was also diabetic, which was probably a complicating factor. This patient was treated with thiouracil for 54 days, with a dosage reducing from 0.8 g per day to 0.4 g. In total she received 30.8 g of thiouracil over the course of treatment. Her death occurred 5 days after the symptons of agranulocytosis began. Agranulocytosis was the main cause of death but jaundice and lung congestion were also present.

Ferrer and co-workers (1945) reported the death of a 70 year-old man from agranulocytosis after thiouracil treatment. They were unable to halt the fall of the white cell count and there were also kidney effects. They suggest that the reaction was not due to a cumulative effect but rather to the development of sensitivity to thiouracil.

A non-fatal case of agranulocytosis was reported by Astwood (1943). This man developed the condition 37 days after the start of treatment with thiourea, having had a total of 43 g of thiouracil. Astwood suggests that patients should be given either 1 to 2 g of thiourea or 0.2 to 1 g of thiouracil as a daily dose.

Fishberg and Vorzimer (1945) found that 2% of hyperthyroid patients under treatment with thiouracil showed a fall of their granulocytes, but the cells recovered if the dosage was reduced or withdrawn.

It would appear that thiouracil has a definite effect on the leucocyte producing cells of the bone marrow. Warren (1945) showed that thiouracil was able to depress the respiration of rabbit bone marrow cells in vitro. Paschkis and co-workers (1945) have shown that thiouracil will inhibit cytochrome oxidase activity in rat thymus tissue in vitro.

5P.15d Repeated PTC Testing in Humans

In 1960 Skude rested 8 subjects who had reported PTC as having a sweet taste. The number of times the subjects were tested varied from five to fifteen. The Harris and Kalmus method was used.

Glanville and Kaplan (1965a) used a modified Harris and Kalmus technique with PROP instead of PTC. They tested 23 subjects three times weekly for 4 to 9 weeks. In the preparation of PROP the initial solution from which the serial dilution is taken contained 1.02 g of propylthiouracil per litre. Rubin and co-workers (1962) suggest that in using the Harris and Kalmus method the subjects should be tested with PROP once or twice a week for three weeks as a training period.

From the various reports of toxicity of PTC and thiouracil it would seem inadvisable to undertake repeated testings of the same individuals. It is certain that there are species differences in susceptibility to PTC, but until the situation is more fully explored it is felt that great care should be exercised in the use of PTC in taste tests.

It might be possible to introduce modifications to prevent the subjects from swallowing large quantities of the solution; perhaps a wine tasting procedure could be adopted. It would also seem reasonable to notify intending subjects of the possible toxic nature of the substance. It is unlikely that many of the usual volunteers would be eager to sample a potent rat poison, however dilute.

5Q - Laterality Variables

5Q.1 Introduction to Discussion of Laterality Variables

In view of the significant interrelationships between the ten laterality variables (see 5Q.7) it is appropriate to discuss the results of these variables in a single section. This procedure has already been used in reporting the results of the laterality survey (see 3K).

5Q.2 General Frequency of Left Dominance

There is some difficulty in comparing the results of different surveys of laterality, as the reported frequencies in each case are dependant on the definition of left dominance. In studies that combine a number of activities to give a total estimate of laterality there may be differences between these activities, but the raw data is not available. Even when laterality is defined by reference to a single activity such as handedness in writing it is uncertain whether the results are comparable, as most laterality variables are subject to environmental pressures, which may vary from one sample to the next. Both the country of origin of the sample, and the date at which the survey was undertaken may influence the results.

Chamberlain (1928) found that 4.3% of a sample of American college students were left handed in writing. But Rife and Schonfeld (1944) found that the frequency of left-handedness among Jewish American students was 19.0% while that among the Gentiles was 9.1%. They included several activities in deciding lateral dominance. Among American servicemen Karpinos and Grossman (1953) found that 8.6% were left-handed.

In Clark's survey of the laterality of Scottish school children (1957) the total percentage of left writing schoolchildren was 7.0, while in the activities tested on a small sample the percentage of left dominant children varied from 6.1% for throwing a ball to 37.0% for using a peephole. Few of her laterality activities were shared by the present survey but she recorded 11.2% left handed and 6.1% undecided in unscrewing a jartop, 6.7% left footed kickers and 2.1% ambilateral in kicking. Probably the test involving sighting down a cylinder may be said to come nearest to the eye dominance test in the present survey. Clark found that 36.1% of the subjects were left-eyed for this characteristic.

In a Swedish sample Beckman and Elston (1962) found that the general frequency of left-handedness was 5.4%, while regional samples varied between 5.5% and 7.1%. Pelecanos (1969) noted that the proportion of left handed Greek children in the 6.9 age range was 11.1% while 9.6% of the 10-12 year old children were left handed. This estimate of handedness was derived from several laterality activities. Annett (1967) quotes frequencies of left handed between 2.0 and 5.0%, but she also classifies between 25.1 and 37.0% as having mixed dominance. Some authors have noted a raised frequency of left dominance in twins, but Shields (1962) found that 10% of the monozygotic individuals were left handed, as were 12% of the dizygotic group. These results may seem to indicate a higher level of left dominance in twins if they are compared with the previous data, however Shields' results are in good agreement with the present survey data. Clark (1957) quotes Wilson and Jones (1932) as having found frequencies of 10.7 to 12% left handed in twin samples, while only 6.5% of the single born were left handed.

In the present survey it was found that 10.9% of the total sample were left handed in writing. This was the lowest frequency of left handedness in any of the activities involving hand use. It is possible that the environmental pressure to conform in writing is stronger than that involving other activities. In more purely practical activities such as racquet use in sport and threading a needle it seems likely that the more skilful hand would be used despite convention. In the non-writing laterality activities the percentage of left dominance varied from 11.7% in use of a racquet to 23.2% in unscrewing a jartop. In Clark's 1967 survey the total of persons left dominant or ambilateral for this activity was 17.3%, which is in moderate agreement with the present result.

The frequency of left eye dominance in the present survey was 30.1% which is in good agreement with the data of Clark (1957). Belmont and Birch (1963) found that 31% of their sample of children had dominant left eyes. This higher frequency of left eye dominance would seem to indicate that this trait differs from the other laterality variables in some way. This point will be discussed fully at a later stage.

Both the foot activities were found to show a comparatively large percentage of ambilaterality in addition to the left dominant group. This may indicate that skill determines foot usage, but it may also represent the reduced social pressures with regard to foot activities. No comparable data was available for stamping but Clark's survey showed that only 6.7% were left footed kickers and a further 2.1% were ambilateral. In comparison the present survey showed 10.4% left footed and 14.3% ambilateral. These proportions are much smaller than those of the present survey, and it is difficult to put forward any explanation of this difference. In the Clark survey the children were Scottish, and the age range was from 11 to 12. It is unlikely that the regional difference would affect this trait, nor is the age difference sufficient to cause confusion. It may be that the performance of the test has tended to affect the results. In the present survey the subjects mimed the kicking of a ball, whereas in Clark's survey the action was actually performed. (see 3R.1)

5Q.3 Sex Differences in Laterality

During the present survey it was found that there was a larger proportion of left dominant males than females in each of the laterality activities. In five of the laterality activities this difference was statistically significant, with percentage differences between the sexes of 9.2% for card dealing, 6.3% for racquet use, 9.7% for unscrewing a jartop, 9.7% for stamping and 11.7% for kicking. If the remaining laterality activities eye dominance showed little sex difference with only 2.6% difference between the two groups. But in the other 4 activities the percentages of left handed in the single sex groups differed by 3.8% in writing, 6.6% in throwing a ball, 3.9% for needle threading and 5.7% in hammer use.

Thus it would seem that there is a consistent bias towards a greater proportion of males being left dominant in laterality. Though no reports of significant sex differences in laterality have been found, other workers have noted slight differences that appear to follow the same trend. Clark (1957) found 8.0% of boys wrote left handed in comparison with 5.9% of the girls. In Chamberlain's survey of 1928 the percentage of left handed students was 5.0 for males and 3.4 for females. A slight difference was also noted by Wheatcroft (1967) who found 10.3% of male students were left handed in comparison with 9.1% of female students.

It is possible that there are sex differences in the pressure put upon the child to conform in handedness. However handedness is determined at an early age, before the child has encountered the various tools and equipment that tends to be designed for the right handed. That the home environment influences the development of handedness was shown by Chamberlain (1928). She found that in homes with one left handed parent, 13.8% of the children of a left handed mother were left handed, in comparison with only 9.7% of the children of a left handed father. But this does not explain the present sex difference. If laterality is determined by a number of genetic factors acting in association with environmental influences, it could be that a sex linked factor giving an additive predisposition towards left dominance is among these factors. This would account for the sex differences noted and might contribute to the maternal/paternal differences observed by Chamberlain.

As the present survey involved miming for eight of the ten activities it could be that the percentages of left dominant reported do not correspond to the real totals. It could be that there is a sex difference in the children's reaction to being asked to mime these activities. In this case one would have to suggest that the females in the sample were more anxious to conform, by classifying themselves with the majority of right dominant subjects, than were the males. However the one activity other than eye dominance that was actually performed by the subjects was unscrewing a jartop. There was a significant sex difference in this trait, and so it would seem that the sex difference exists whether the activity is performed in practice or mimed. (see 3R.1)

5Q.4 Association of School Type with Laterality

The sex differences in laterality discussed in the preceding section may be partially responsible for the situation regarding the association of laterality with school type. As previously stated in the results section it was found that in general the male non-selective sample contained an excess of left dominant males, while in the female sample the excess left dominant girls were found in the selective group.

In the two significant comparisons in the male sample (writing and dealing cards) the percentage differences between the non-selective and selective school samples were 10.2% and 11.8% respectively. However in eye dominance and threading a needle there was a slight excess of left dominant boys in the selective schools, but these differences were small. In the remaining six laterality activities the percentage differences between the school types ranged between 1.0% and 10.6%.

Among the females the only association that did not show an excess of left dominant subjects in the grammar school group was unscrewing a jartop. All the remaining comparisons had excess left dominant selective girls, with percentages ranging from 0.8% to 6.6%. None of the associations were statistically significant.

No previous survey investigating the possibility of an association between laterality and school type has been found. It is of interest to note that Karpinos and Grossman (1953) found a greater percentage of left handed men among rejected recruits than among those accepted for the US forces. They suggest that hand dominance could be associated with other defects. Though there were only 2.2% more left handed men in the rejected group than the qualified group this difference was sufficient to give significance as the sample size was extremely large.

It is possible to suggest that left dominance is in some way associated with handicapping factors, or that left dominance itself is sufficient handicap to influence the apparent ability of the individual. This would explain the lack of left dominant males in the selective school sample, but the excess females in this group remain a problem. As there is a greater overall proportion of left dominance in males it might be that one factor influencing laterality is sex linked. If this factor also tended to produce some decrease in ability this would explain the sex difference in the distribution of left dominance in the two school sample.

Eye dominance is again distinct from the other variables, showing comparatively little variation between school types in either sex, and reversing the general trend in males. The reversal of the general trends in needle threading in males and jartop unscrewing in females is unlikely to be of any major importance. This is probably the effect of sub-dividing the samples. (see 3R.2)

5Q.5 Association of Laterality and Social Class Background

Though there were no significant differences in laterality between the social class groups there was a tendency for the professional group to contain a greater percentage of left dominant subjects than the other two groups. This trend was shown by the male sample and by the total sample, but among the females only four of the laterality traits showed excess left dominance in the professional group. Of the remaining traits five showed the greatest frequencies of left dominance in the middle class group, and one (dealing cards) has the greatest left handed frequency among the manual group girls.

In the survey of students by Wheatcroft (1967) it was found that both males and females showed a raised percentage of left dominance in SC 1. Among the females SC IV and V also showed an increased percentage of left dominance, but this was probably the result of the small sample size. This result would seem to support the present survey data, though it is not possible to explain the present excess of left dominant females in the middle class group.

Since the male sample showed a significant association between left dominance and non-selective school type it is difficult to explain the present tendency towards excess left dominant subjects in the professional group. The school data would lead one to expect a raised percentage of left dominant males in the manual group, with a possibility of excess left dominant females in the professional group. However neither of these predictions is correct.

It would seem that the factors giving rise to the association of laterality and school type are independant of those influencing the distribution of lateral dominance in the social classes. There may be differences in environmental pressures in the various social class groups. The combined effect of social class and sex differences in the pressure to conform in laterality could give the present results. (see 3R.3)

5Q.6 Association of Laterality and Parental Origin

There were no significant differences in laterality when the three parental origin groups were compared. Nor were any previous surveys involving this possible associated noted. There were no clear trends in the results, and the maximum frequencies of left dominant subjects varied from group to group according to the trait under study. It is of interest to note that for eye dominance the greatest frequencies of left laterals were found in the Midland sample of both sexes and in the total sample, while the greatest frequencies of left handed needle threaders were found among the English. In all the other laterality characteristics there were differences between the samples regarding the maximum frequency classes. It seems probable that laterality is not associated with geographical distribution, but it may be that the present method of defining parental origin has led to a loss of information. (see 3R.4)

5Q.7 Association Between Laterality Variables

It might be expected that there would be a high degree of association between the lateral dominance of the various laterality activities in each subject. In the present survey the subject was asked to mime the majority of the survey activities. This factor could have added to the correlation between the various activities, as the subject might hesitate to give an account of inconsistency in laterality activities, whereas if the activities were performed in practice the true behaviour could be observed.

The results show that the majority of the possible associations between pairs of laterality activities are statistically significant in both the total sample and the single sex samples. The one activity which seems to be less strongly associated with other laterality variables is eye dominance. All the pairs of activities that were found to lack significant association involved eye dominance, and most of the associations with low levels of significance also involved this character. Thus it seems that eye dominance is distinct from the lateral dominance of hand and foot.

The independance of lateral dominance of eye and limbs has been noted by several workers. Woo (1928) and Woo and Pearson (1927), found that only 25% of their sample had their greatest visual acuity on the same side as their best grip strength. They found little relationship between ocular and manual activities. Merrell (1957) found that 29.3% of the sample showed the phenomon of crossed dominance, having different lateral dominance reactions for hand and eye. Clark (1957) found that though eye dominance was not related to handedness, there was a significant association between eye dominance and lateral differences in hearing. A later study by Belmont and Birch (1963) noted that only 48% showed consistency in dominance, the remainder being 'crossed' or mixed in lateral dominance. Collins (1961) discussed the lateral dominance of thumb, wrist, elbow and shoulder and noted that 88% showed mixed dominance.

In the present survey it has been found that there was no apparent difference in the frequency of left dominant subjects in the mimed manual activities and the one performed activity. It is therefore unlikely that the action of looking through a kaleidoscope would provoke a falsely large proportion of left dominant persons. From this it must be concluded that the observed difference of the eye dominance distribution from the remainder of the laterality variables represents a real variation rather than an artifact caused by the survey methods.

The percentages of subjects showing crossed dominance for eye and hand activities ranged from 27.5% for eye/writing preference to 35.4% for eye/unscrew jartop and eye/thread needle. Crossed dominance for eye and foot occurred in 35.6% for eye/stamp and 37.6% for eye/kick. These figures are in fair agreement with the results of previous surveys.

It is well accepted that eye dominance shows some degree of independance from other forms of lateral dominance. However the methods by which the various factors determining laterality interact to produce this result is not known. Both eye dominance and general lateral dominance have been shown to be determined in part by hereditary factors (Merrell 1957), but it may well be that these factors are unrelated. It would be expected crossed dominance would be disadvantageous to the individual, but the high level of this type of combination in the population may indicate that this is not the case. (see 3R.6 to 3R.50)

Association of Laterality and Metric Variables

see section 5R.17

Association of Writing, Unscrewing a Jartop and Finger Type

see section 5N.3

Association of Dealing Cards and Threading a Needle with PTC Tasting

see section 5P.14

Association of Eye Dominance and Ocular Defects

see section 5F.4

Association of Stamping and Skin Type

see section 5L.2

Association of Kicking Ball and Hair Type

see section 5H.2

5Q.8 General Discussion of Factors Influencing Laterality

It is known that there is a strong hereditary component in the determination of laterality (see section 2T.4), but it has not yet been possible to suggest an explanation for the present complex situation. Roos (1935) has suggested that the environment of the foetus might affect the lateral dominance of the child, though this could not be demonstrated. One aspect of the uterine environment that is known to vary polymorphically is the direction of the helix of the umbilical cord. Malpas and Symonds (1966) found that 79.6% of cords had a left handed helix and 20.4% a right handed helix. They suggest that this variation is genetically influenced.

Since the foetus is known to touch and hold the umbilical cord it is possible that the direction of the helix could in some way influence the individual's future laterality. One helix type will fit the left hand better than the right and vice versa. The influence of this cord helix factor would be acting upon the basic genotype of the foetus, together with the post natal environmental factors to give the total laterality result. It would be comparatively easy to test this hypothesis by a longitudinal study of infants from birth to established laterality.

5R - Metric Variables

5R.1 General Points

It was found that the majority of the previous surveys of metric variables had only included height and weight. There were a lesser number of studies concerning ponderal index and foot measurements, but very few involving the obesity index. Similarly there are few studies involving comparison between children from different types of school, while a large number of surveys have investigated the effects of social class background.

5R.2 Sex Differences in Metric Variables and Comparison with Previous Surveys

In adults there is a considerable sex difference in weight and body measurement; males on average being 10% greater in these measurements than females (Tanner 1962). However in an adolescent group this relationship may be obscured by the sex difference in the timing of the growth spurt. In general the growth spurt in girls occurs two years before that in boys. The period of maximum growth in girls is usually from 10½ to 13 while in boys the growth spurt occurs between the ages of 12½ and 15. From this it will be seen that in a sample of 14 and 15-year-olds, the majority of the girls will have completed the growth spurt, while some males may not yet have entered this phase. Frisch and Revelle (1969) found that maximum growth in height occurred at a mean age of 11.8 years in females and 14.0 in males, while maximum weight growth occurred at 12.1 years in girls and 14.1 in boys. Tanner and co-workers (1966) found that the age of peak growth in height was 14.1 years in males and 12.1 years in females, while peak growth in weight occurred at 12.9 years in females and 14.3 years in males.

There is of course much individual variation in growth pattern. Reed and Stuart (1959) divided the phases of growth into three periods: from 0 to 6 years, 6 to 12 and 12 to 18. By classifying the child's growth in each period as slow, moderate or rapid they were able to distinguish 27 possible pattern types. Physical maturation is also linked with sexual development. Garn and Haskell (1960) noted that those girls of their longitudinal study who showed extreme fatness or thinness were separated by five years difference in menarcheal age, as well as a difference in growth rate. Wollf (1955) found that puberty was advanced by one year among obese children, but that tall children were also ahead of the remainder of the group by an average of six months.

In a sample of public school children Clements (1954) found that the average age at which growth in height stopped was 17 years 9 months in males and 16 years 3 months in females. In contrast Montegriffo (1960) found that growth in height continued until over 25, and Clements and Pickett (1954 a & b) found that in men growth in weight and chest girth continued until the age of 30. In the present sample it would seem that although many would have passed the adolescent growth spurt, all would still be in an active phase of growth.

In the total UK sample there were significant sex differences in all the metric variables except weight. The West Indian and Asian samples were probably too small to provide meaningful results, but it is interesting to note that the Asian sample appeared to follow the UK pattern, with significant differences in all variables except weight and obesity, while the West Indian sample showed only one significant sex difference, in foot length.

The height means for the sexes in the main UK sample were 166.4cm for the males and 159.0 for the females, a mean difference of 7.4cm. Knott and Meredith (1963) noted that the mean for 15-year-olds was 168.9, so it would seem that the mean of the present 14 to 15-year-old sample is in good agreement with this result. In a survey of the heights and weights of London schoolchildren Scott (1961) found that in the age group 14 to 15 the height range was 135 to 185cm in males, and the females heights ranged from 130 to 190cm. These ranges are very similar to those found in the present survey. Keddie (1956) found that the mean heights for Scottish sixteen-year-olds were 172.0cm for boys and 161.7cm for girls.

It is interesting to note that there was no significant sex difference in weight in either the UK sample or the two non-UK samples, though the UK sample showed a significant difference between the sexes in obesity. These results may be due to considerable fat changes at adolescence. Hunt and Barton (1959) found that these changes were sufficient to confuse attempts to repeat the somatotyping of a group of boys. There are sex differences in the pattern of fat deposition. Lombard (1950) has noted a pre-puberty increase of fat in males but not in females and Kornfeld (1957) confirms this. Lombard also stated that at the age of 16 the average male has 10% of his body weight as fat, in comparison with 20% in the average female. This difference in body fat continues to develop until the age of 16 (Eichron and McKee 1953) however there may be a decrease in fat deposition between the ages of 13 and 17. Hammond (1955) found that in females fat deposition increased steadily until 15 while in males there was a rapid increase from 7 to 11, and then a slow rise until 17. Similarly Garn and Haskell (1959) noted a steady increase of fat in girls, but in boys there was a reduction in fat deposition after the age of 11. Reynolds and Grote (1948) noted that females tended to gain fat at puberty, while Garn and Saalberg (1953) found that mature females continued to gain fat. Garn and Young (1956) suggest that in the female there is a redistribution of fat at maturity with loss of subcutaneous fat and gain of deposits elsewhere.

The mean weights of the male and female sample were 53.47kg and 52.46kg respectively. These results are somewhat lower than those of Knott and Meredith (1963). In a sample of American boys these workers found that the mean weight for fourteen-year-olds was 55.9kg, while the mean of the fifteen-year-old group was 61.5kg. The range of weights in the London school sample examined by Scott in 1961 was 28 to 100kg in males and 32 to 100kg in females, which is in good agreement with the weight range in the present sample. In a sample of Scottish schoolchildren Keddie (1956) found that the mean weights for sixteen-year-olds were 60.7kg for males and 55.6kg for females. In this case the high values are probably the result of the greater age of the sample, but it is possible that regional differences in height exist within the British Isles.

The results for mean ponderal index and mean obesity index show that the females are significantly more endomorphic than the males. This is the result that would be expected from the previous discussion of fat deposition differences in the two sexes. Both the ponderal index and the obesity index are expressions of the linearity of the subject and there is therefore a link with the somatotype of the subject. It is however uncertain whether any form of somatotyping of adolescents is valid. Barton and Hunt (1962) found that there were changes in the somatotype rating of a group of boys seen at the ages of 11.5 and 17 years. In a previous study (1959) Hunt and Barton found that there was good agreement between the pre- and post-puberty ponderal indexes of a group of boys, though the correlation of the two sets of somatotype ratings was poor. Ponderal Index is known to be correlated with the various somatotype components. Munroe and co-workers (1968) found that the ponderal index in a sample of 12 year-old boys showed a correlation of -0.85 with endomorphy, -0.69 with mesomorphy and +0.96 with ectomorphy. There is also a basic relationship between somatotype, skeletal maturity and sexual maturation.

Acheson and Dupertuis (1957) suggested that this relationship was genetically controlled, though environmental influences were also effective.

Foot length was studied by Blais and co-workers in 1956. They concluded that there was no sex difference in foot length until the age of 12. At this stage the average lengths were 23.2cm for girls and 23.5cm for males. After this the boys' feet grow for another four years, gaining an average of 2.7cm, but the girls' feet only continue to grow for two years, gaining another 0.8cm on average. This gives average mature foot lengths of 26.2cm for males and 24.0cm for females. In the present survey the mean foot lengths were 25.53cm for males and 23.69cm for females. It may be that the difference between these results is due to the fact that the present sample is not in fact a mature one, but the results are still in good agreement. Blais and co-workers also found that the growth of the foot was completed before that of the leg bones, and that the leg bone growth finished two years before the completion of growth in height. Anderson and co-workers (1956) noted that the adolescent spurt in foot growth precedes the growth spurt of the leg bones and total stature by a period of six to eighteen months. Foot growth is still synchronised with body growth such that the measurement from heel to toe remains in the same proportion to the heel to head measurement throughout the growth period. Davenport (1932) also noted the pre-adolescent growth spurt in foot length.

In an account of foot size from the embryo to maturity, Meredith (1944) suggests that the average female foot is nearer to its adult size at all stages than is the male foot. By the age of ten the female foot has reached 90% of its eventual length whereas the male foot has only grown to 82% of its total. The mean foot lengths for young adults in Davenport's survey were 23.6cm for females and 26.1cm for males, both measurements showing similarity in the present survey results. A survey of women's feet organized by the Shoe and Allied Trades Research Association (Manning 1955) found a mean foot length of 23.6cm for women of all ages, while the mean for the younger group (16-25 years) was 23.8cm. Hill (1958) studied the feet of a group of girls over a period of nine years. He found that the front part of the foot tended to broaden with increasing age, particularly in adolescence. He suggests that this might be due to increasing weight. The present survey finding of a significant sex difference in foot width probably reflects the difference in total foot size. (see 3S.2)

5R.3 Association of School Type and Metric Variables

It is almost impossible to isolate the effects of one environmental factor on physical development, as any situation contains a complex of such environmental factors. Often these factors are found to be associated with one another, as in the present survey where social class background and schooltype are significantly associated. However in a study by Douglas and co-workers (1965) the subjects were selected for equivalence in sex, age, stage of sexual development, social class and family size. In this survey there still remained a correlation of 0.15 between height and measured ability. Berry and Cowin (1954) found that grammar school boys were heavier than secondary modern school boys. Each social class group within the grammar school group was heavier than the same class in the secondary modern sample. In a Swedish survey in 1942, Broman et al found differences in height between children of both sexes at secondary and elementary schools. (In this case there was selection for ability for entry to the secondary schools) Hammond (1953) compared the development of children at public or preparatory schools, council schools and slum schools, and concluded that the public school children were two years ahead of the others in growth. However not all public schools are beneficial in their effects. Widdowson and McCance (1944) suggested that certain boarding schools might provide inadequate food, as the pupils gained weight more rapidly at home than during the term time. Friend and Bransby (1947) found that boarding school boys tended to gain weight during the second hald of each term. They also distinguished three standards of boarding school, A, B and C. Day boys and pupils at Grade C schools were similar in height, but Grade B pupils were larger, and Grade A school pupils were the largest of all.

It may be that there is an association between size and mental ability as the work of Douglas et al (1965) suggests. Maxwell (1953) found that high IQ children were 2.3cms taller and 6.3lbs heavier than average. However Laycock and Caylor (1964) compared pairs of siblings where one member of each pair was "gifted", in terms of IQ. The IQ range of the gifted sibling was 120 to 199 while the less gifted siblings ranged from 80 to 134. There were no significant differences in height, weight or any anthropometric measurements between the two groups. Similarly Price (1969) has shown that there was no significant difference between psychiatric patients and their normal siblings for a number of anthropometric measurements.

From the above data and from the literature on social class differences (see sections 5R.4, 5R.5) it might be expected that the grammar school pupils would in general be larger than the non-selective school pupils. However the results in the present survey proved to be complex with height and ponderal index showing significant differences between school types, but with opposite trends in the two sexes. Among the females the grammar school girls were significantly taller and more linear in build than the non-selective school girls, while the grammar school boys were shorter (though not significantly) and stouter than the comparable non-selective sample, by ponderal index. It is difficult to explain these results but one possibility is that there is a difference in the timing of the growth spurt in the two school groups. Since social class background was found to be significantly associated with school type it is possible that this could reflect some difference in timing of the growth spurt in the social classes, however the results of the social class comparison (see section 5R.4) would seem to oppose this theory. If the growth spurt was delayed in the grammar school group as a whole, this difference might only be manifested in the male sample in the present survey owing to the fact that the females could have completed their growth spurt whereas the males were still growing. It is possible for an early growth spurt to result in a smaller adult size than a later growth spurt, as the late maturer has a longer period of basic growth before the growth accelerates (Maresh 1955), Acheson and Hewitt (1954).

This hypothesis could only be tested by means of a longitudinal study.

The school type differences in the obesity index were so slight as to indicate a general homogeneity for this characteristic. In weight there were no significant differences but the selective school children were rather heavier. This is in general agreement with the data from previous surveys of weight.

In both the foot measurements the non-selective sample were on average slightly larger. This difference applied to the single sex samples as well as the total. Though the differences were comparatively small it would have been expected that the grammar school sample would have possessed the larger feet. No previous survey of school type and foot size has been found, but it is possible that there may be differences in the type of footwear prevalent at the two types of schools. It is possible that the children in the non-selective school sample were accustomed to wear less formal shoes than the grammar school sample. This behavioural difference might affect the length and width of the foot. (see 3S.3)

5R.4 Association of Metric Variables and Social Class in Children

Tanner (1962) has stated that large people tend to move up the social scale, though the reasons for this trend are not clear. In consideration of the association of size and social class there is always a danger of circular reasoning. One can either claim that favourable social conditions allow maximum growth or that the offspring of the more privileged classes are basically larger than the children of the lower prestige groups. This will be discussed more fully in a later section, and the present section will merely report on the evidence for such an association.

In 1940 Jenss noted that girls aged 6 to 8 from poor socio-economic backgrounds gained weight more slowly than those from good backgrounds. Meredith (1941) found that the sons of the professional classes were on average 3% taller and 6% heavier than the remainder of his sample. When Cambridge primary school children were investigated by Yudkin in 1944 he found that the children from poor areas were on average 0.8 ins shorter and 2.6 lbs lighter than those from prosperous areas.

In a comparison of Canadian elementary school children of two socio-economic trata Hopkins (1947) found that there was a difference of 1.3 in and 3 lbs between the strata. Meredith (1951) reviewed a number of social class studies, and concluded that the professional class boys in the 7 to 10 age group tended to be 1 inch taller and 3 lbs heavier than the average, while the shildren of indigents were 2 ins shorter and 5 lbs lighter. However Greenberg and Bryan (1951) showed that there was no difference in linearity between schoolchildren of different social class. Those in the upper socio-economic group who were taller were also heavier; thus the basic proportions of the children were fairly constant.

Kemsley (1951) published a report on a survey of the height and weight of the population that had been taken in 1943. At this stage the school leaving age was 14, and so he was able to compare the sizes of adolescents in different occupations. Among the males those working in small factories were taller and heavier than those working in large factories, while those who worked in the mines were smallest of all. But in the female sample the girls who came from large factories were taller and heavier than the small factory girls.

The very large scale survey of Scottish 11 year-olds carried out in 1947 was reported by Maxwell in 1953. In this survey there were differences of 3 ins in height and 8 lbs in weight between the extreme ends of the social class scale in the boys, and 2½ ins and 6 lbs difference in the girls.

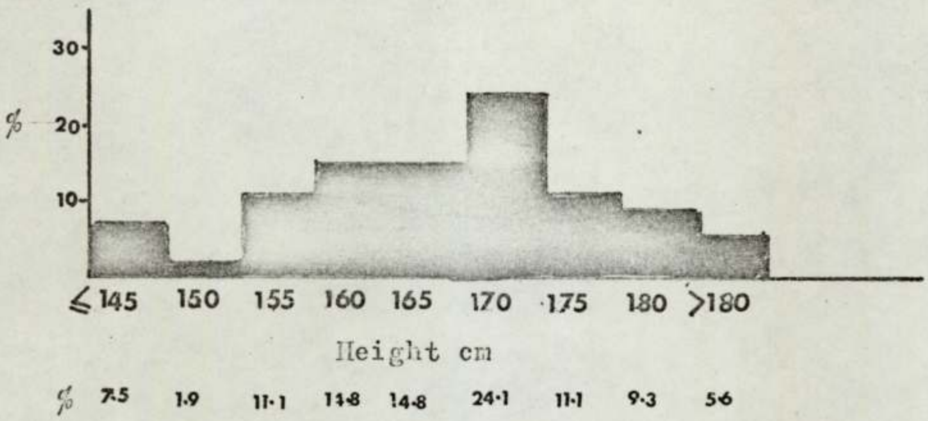
Abramson and Ernest (1954) noted that in a Swedish sample of boys height was associated with social class but weight was not. Berry and Cowin (1954) found that the weights of fourteen-year-old boys were graded by social class as well as by school type. In the grammar school sample there was a difference of 5.5kg between SC I and II and SC V while in the secondary modern group there was a difference of 1.2kg.

Social class differences in pre-school children have been noted by Acheson and Hewitt (1954) and by Hammond (1955b). Wolff (1953) noted that adolescents from professional background were taller than those from other groups. A study of Guatemalan schoolchildren found that there were non-significant differences in height and weight between social class groups, but there was a very significant difference in the serum cholesterol levels of the groups (Scrimshaw et al 1957).

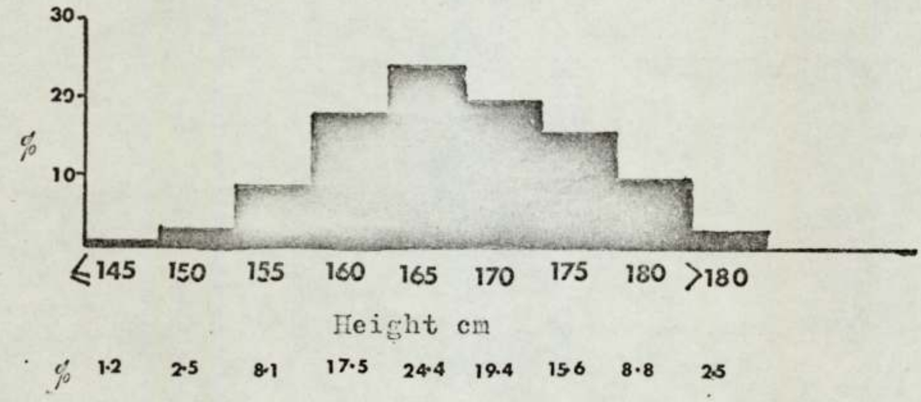
In 1957 Hammond noted that children in better social class

Fig. 17a. Distribution of divided height by class group in male UK sample

Professional



Middle



Manual

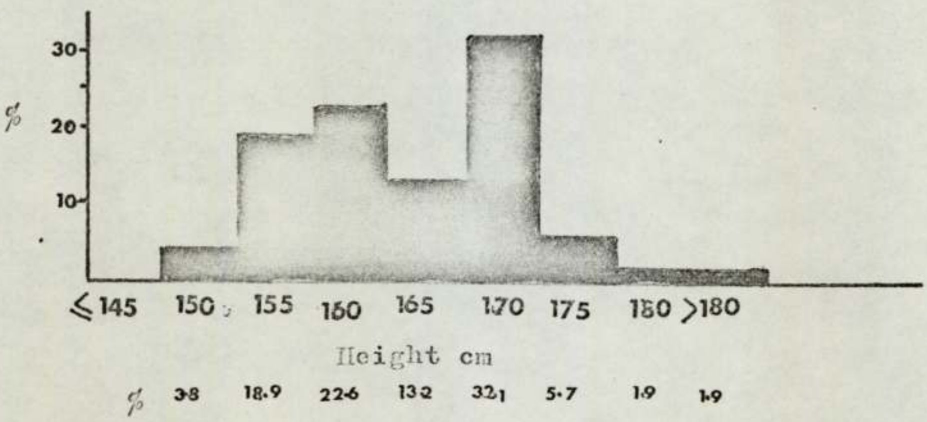
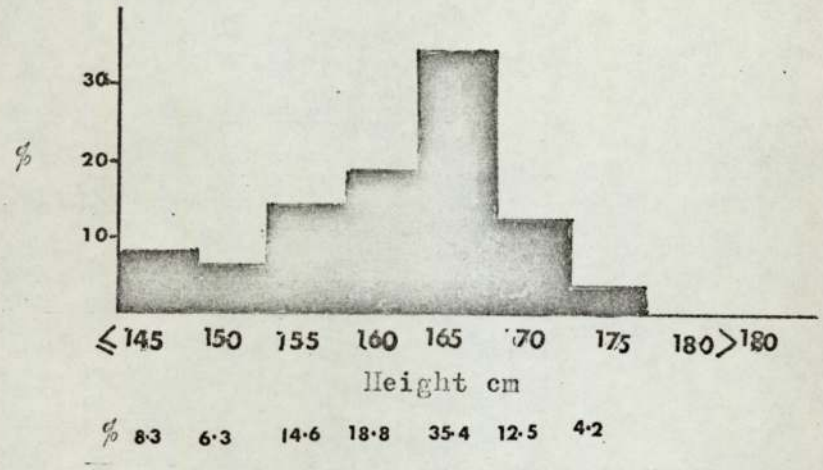
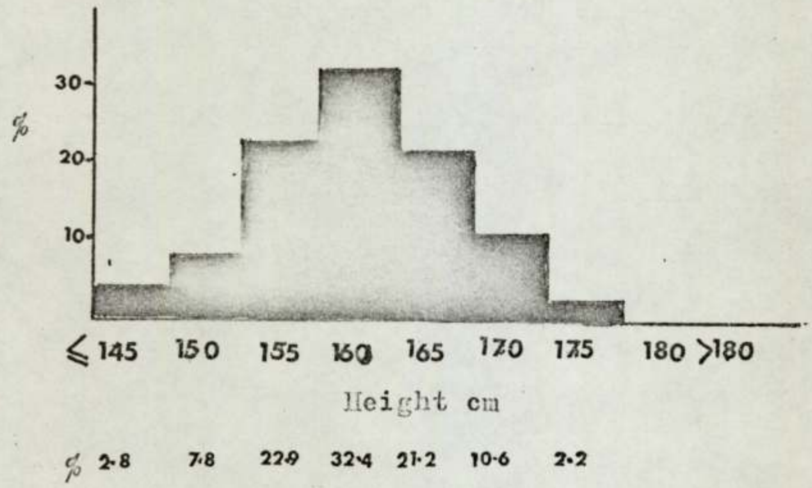


Fig. 17b. Distribution of divided height by class group in female UK sample

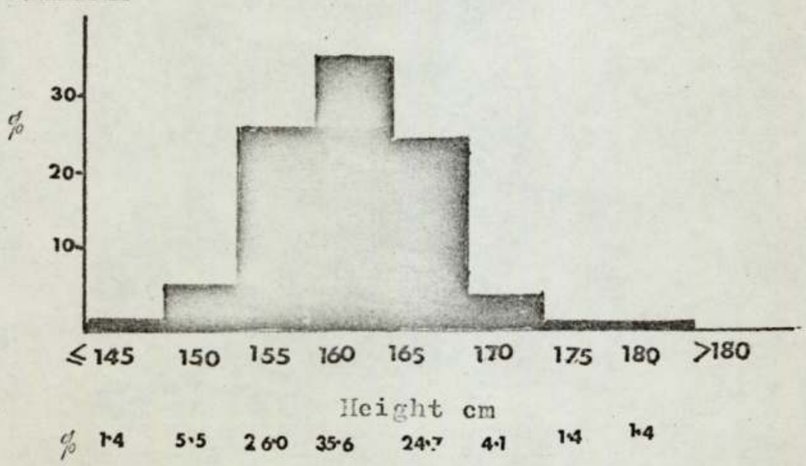
Professional



Middle



Manual



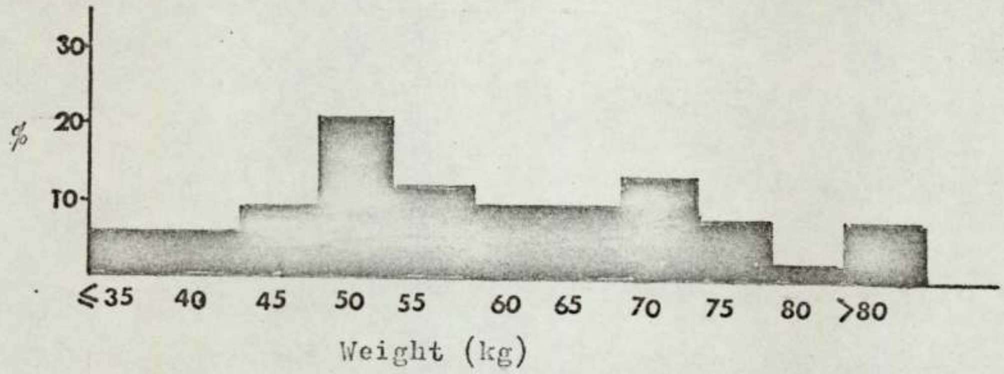
groups tended to grow more in height and this view was also expressed by Keddie (1958) who commented on height and weight. Whitacre and Grimes (1959) found that the social class difference was also present in Texan schoolchildren aged 7 to 14. Craig (1963) found that occupational class was one of the factors influencing the height of Glasgow schoolboys.

Tanner (1966) noted that the difference in height and mental ability between children of different socio-economic groups tended to persist into adulthood. The tendency for the tall to rise in the social scale is probably the result of the association of mental ability and height. In 1970 Topps and co-workers noted some significant social class differences in weight in Kent schoolchildren, though these differences were not present in all age groups.

In the present survey it has been shown that there is an association between increased size and increased social status. However the relationship only appears in the male sample; the situation among the females being less clear. Height, weight, obesity index, foot length and foot width all showed a direct relationship with the social class background of the subject. Those boys from the more privileged end of the social class scale were on average taller and heavier, with larger feet than the boys from the manual groups. There was also a gradation in their weight for height as measured by the obesity index, with the boys from manual backgrounds being lighter at each height. In view of these differences it is interesting to note that the ponderal index results fail to follow the same pattern, there being only very small

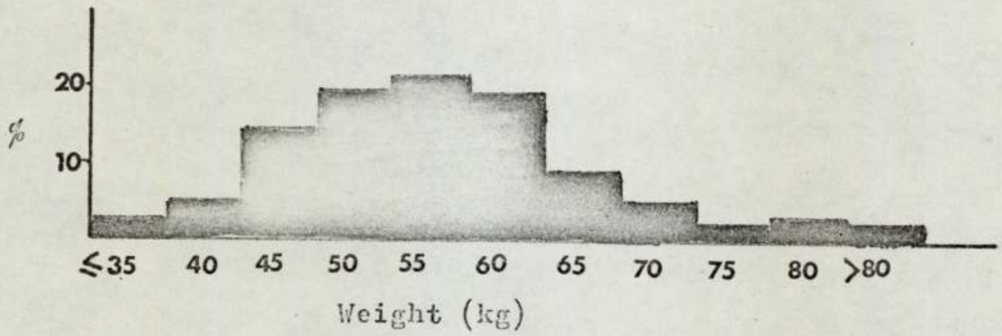
Fig. 18a. Distribution of divided weight by class group in male UK sample

Professional



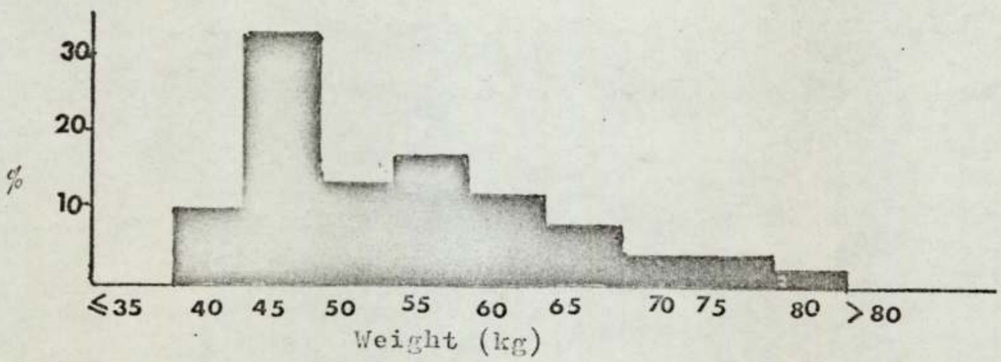
% 5·6 5·6 9·3 20·4 11·· 9·3 9·3 13·0 7·4 1·9 7·4

Middle



% 1·9 4·4 14·4 19·4 21·3 18·8 8·8 5·0 1·9 2·5 1·9

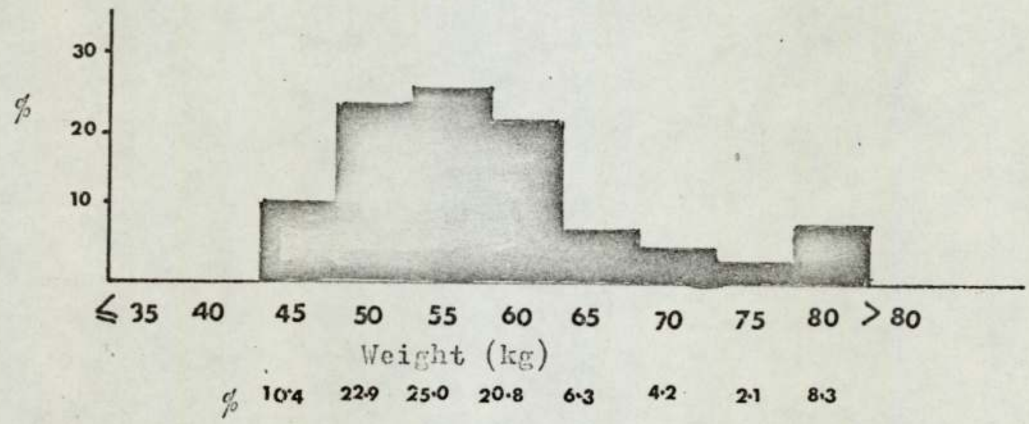
Manual



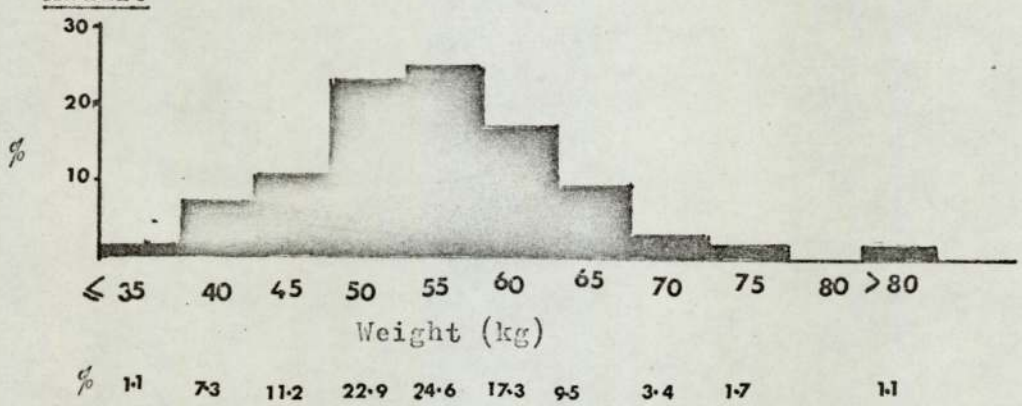
% 9·4 32·8 13·1 17·0 11·3 7·5 3·8 3·8 1·9

Fig. 18b. Distribution of divided weight by class group in female UK sample

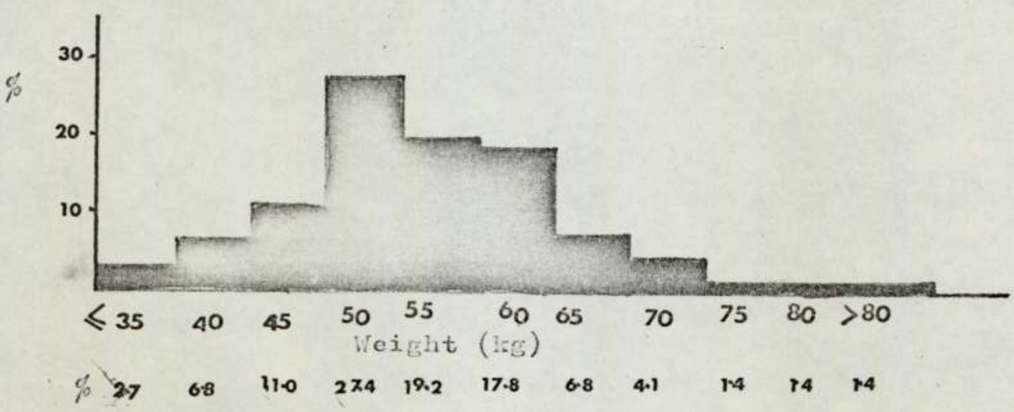
Professional



Middle



Manual



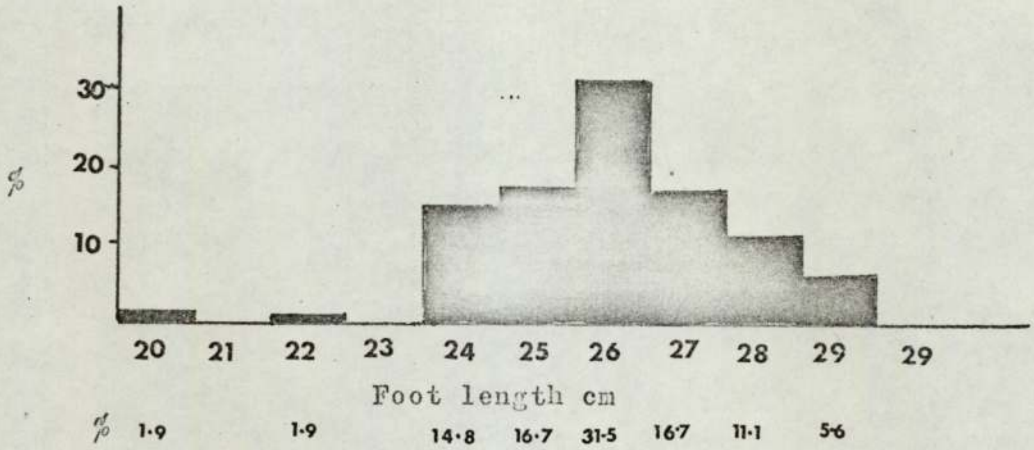
variations in mean ponderal index between the various classes. If it is taken that ponderal index is a measure of body build it would seem that the variation in body build in the present sample of boys is distinct from the variation in size. Factors such as height, weight and foot size in an adolescent sample will be associated with the stage of the growth curve that each individual has reached. (see figs. 17-20)

The only metric variable to show clear gradation with social class in the female samples was weight. In the class groups there may be some confusion because of the inclusion of the girls of unknown parental origin in the manual group. These girls were found to be taller and heavier than those of SC I. However in the social class results as a whole there was a tendency for the SC I girls to be slightly smaller than the SC II girls in height, ponderal index and foot width, but the SC VI girls were larger than the SC II girls in several variables.

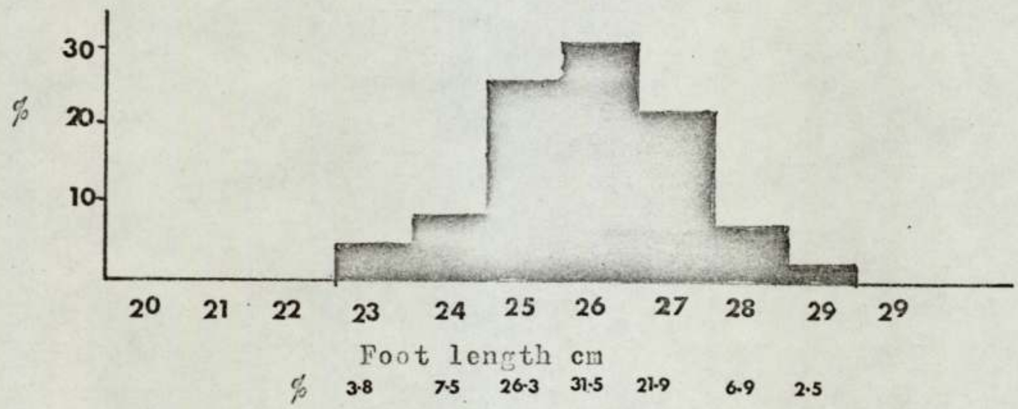
This confusion of trends in the female sample cannot be explained as the simple result of the group being of maximum growth. In fact the majority of the girls would have been expected to be past the adolescent growth spurt. However it is possible that there are social class differences in the timing of the growth spurt. But this hypothesis was used previously to explain the non-selective male sample being on average larger than the selective group. It is unlikely that differences in age of growth spurt would affect males with regard to school type and females with regard to social class. The difference in the pattern of association of the variables with

Fig. 19a. Distribution of divided foot length by class group in male UK sample

Professional



Middle



Manual

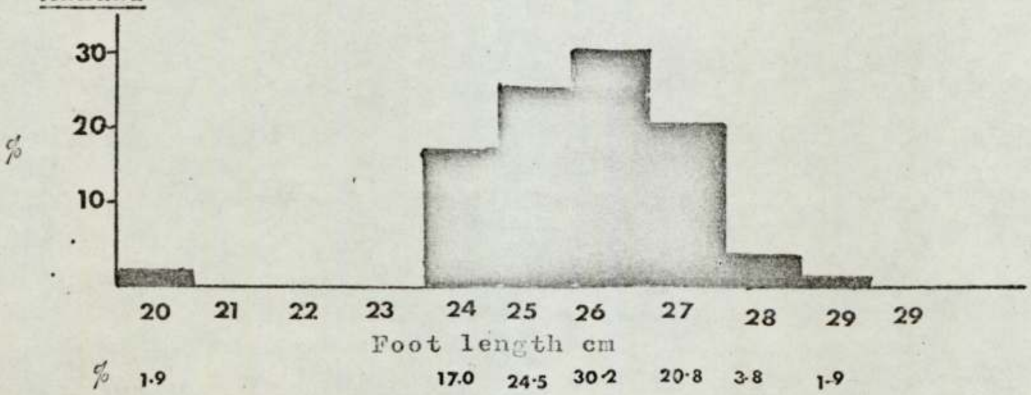
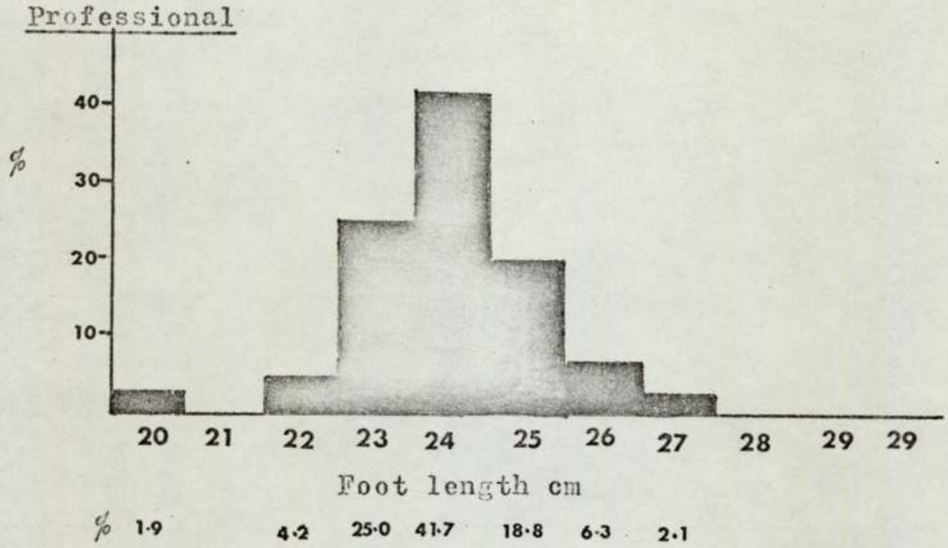
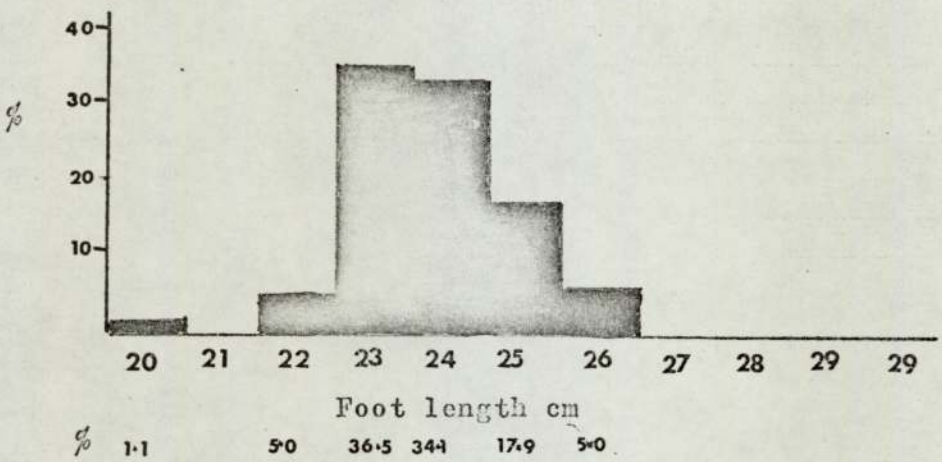


Fig. 19b. Distribution of divided foot length by class group in female UK sample

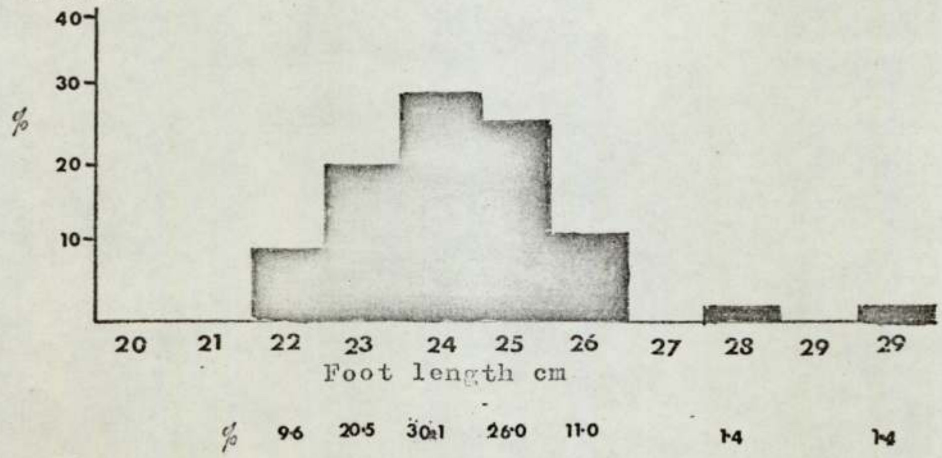
Professional



Middle



Manual



social class in the two sexes reflects the sex difference in the course of the growth curve. If this were the case it would seem that the association of social class and size found in the male sample would be lost at maturity. However results from adult samples noted in the literature (see section 5R.5) tend to confirm the association rather than disprove it. (see 3S.4)

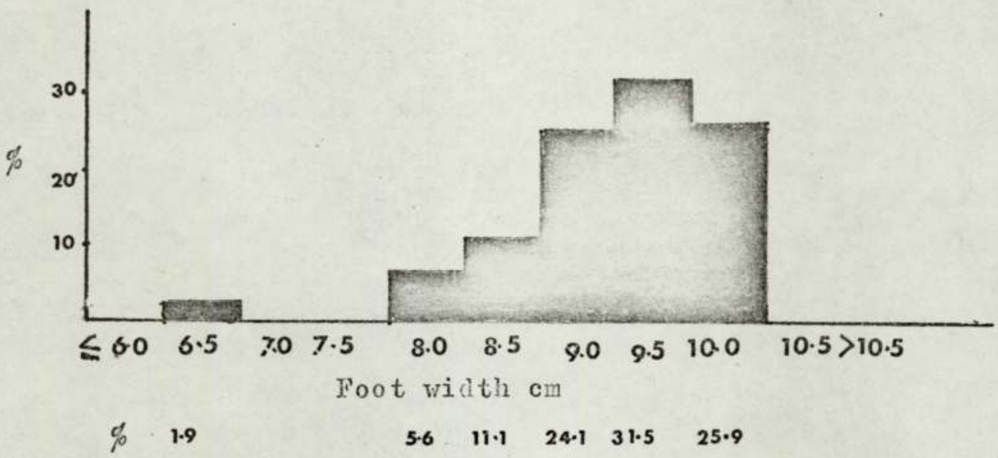
5R.5 Social Class Differences in Metric Variables in Adult Samples

In fact most work on size variation in adult populations refers to occupational differences rather than social class ones. However most social class scales are based on the prestige ratings of the various occupations, and so it seems reasonable to include these surveys under this title. It must be remembered that the original aim of this project was to compare different occupational groups in an adult sample.

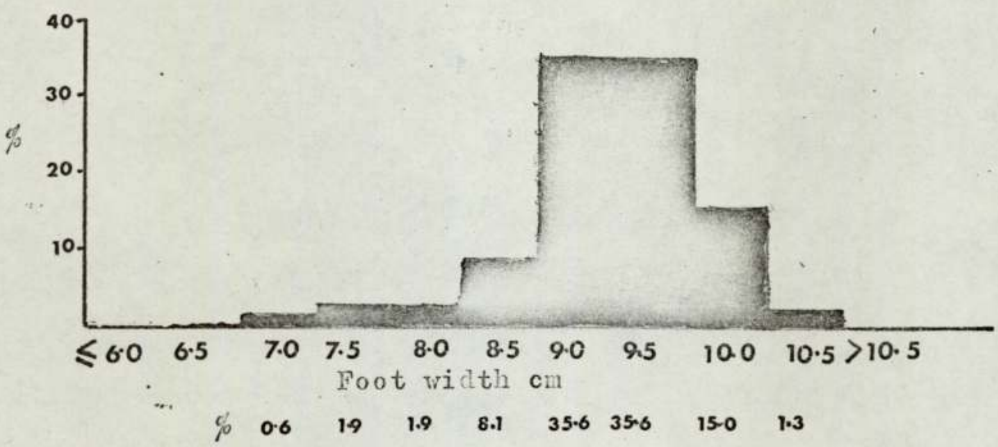
When Schreider (1964) compared groups of peasants with non-agricultural workers in France, he found that the two groups differed significantly in sixteen physical or psychological factors. These included height, weight, right hand strength and intelligence. In general the peasants were shorter and less muscled than the other group, and this difference persisted in all the regions studied, though the average sizes differed from one region to another. By plotting the averages of body height and intelligence of various groups Schreider obtained a correlation coefficient of 0.95. But the figure varied between 0.1 and 0.4 within the single group comparisons. He suggests that stature is not subject to selection but that it is

Fig. 20a. Distribution of divided foot width by class group in male UK sample

Professional



Middle



Manual

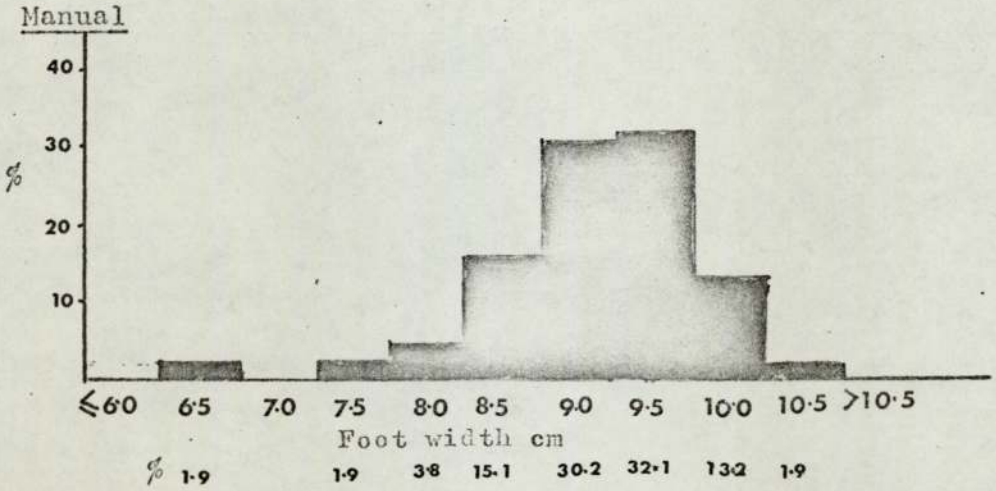
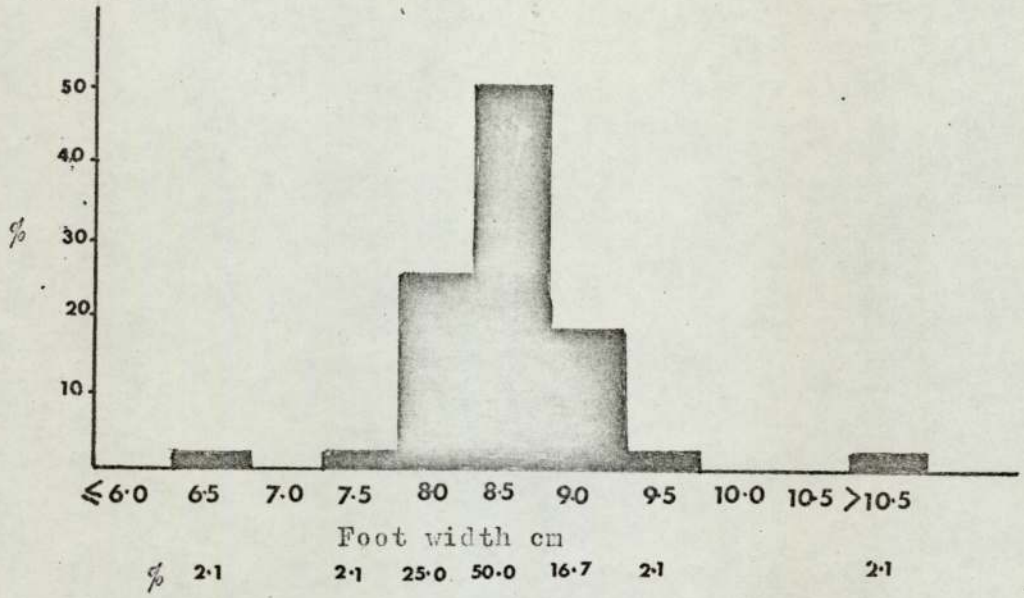
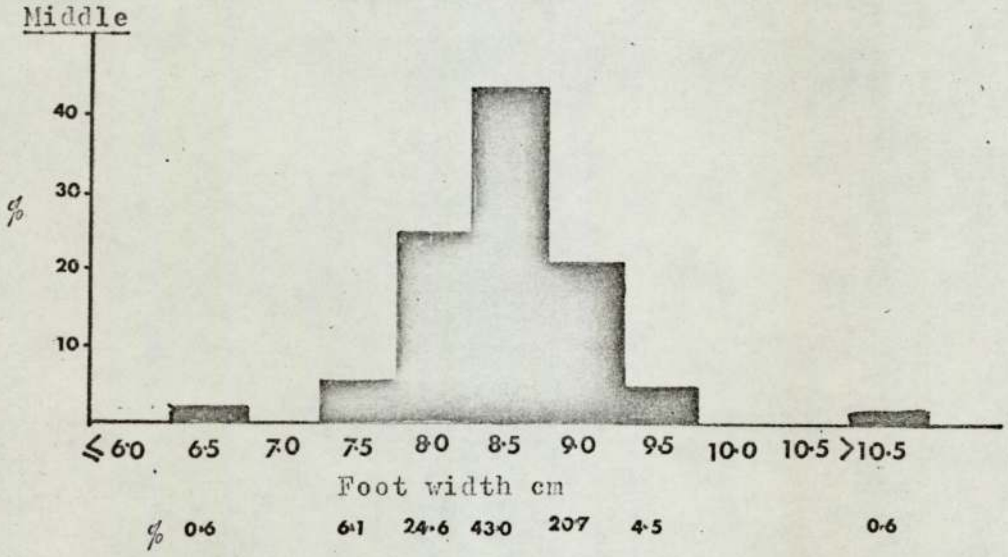


Fig. 20b. Distribution of divided foot width by class group in female UK sample

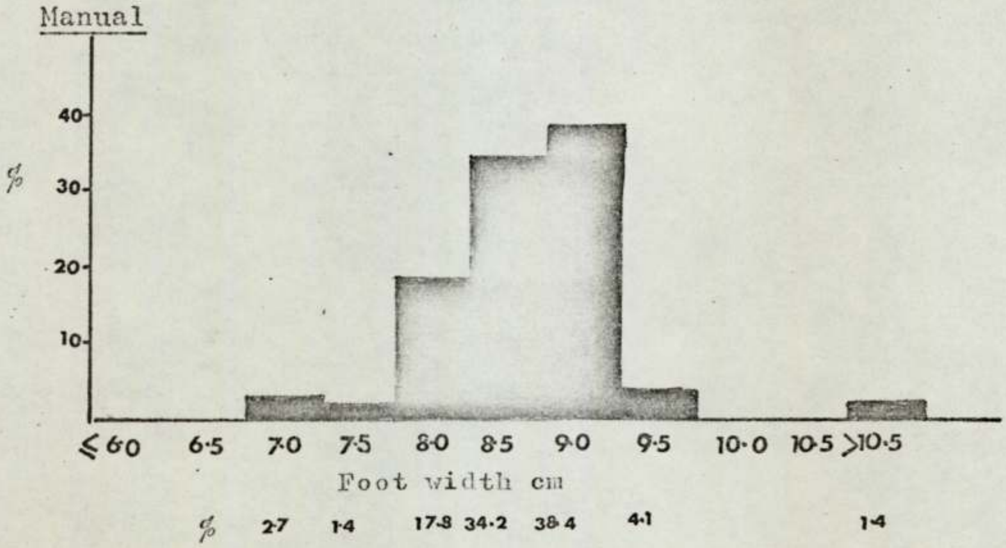
Professional



Middle



Manual



stratified by social class, and admits the possibility that the correlation of mental ability and stature may be an artifact. In a later paper Schreider (1968) found that there was no relationship between economic and social conditions and variation in body height.

In 1954(ab) Clements and Pickett found that there were no social class differences in body weight and chest girth in a large sample of men, though some occupational groups differed from the main body. However in 1957 the same workers found significant differences in height and weight in both social class and occupational groups. This latter survey used data from National Servicemen and the Ministry of Labour. There was a difference of 5 lb and 1.3 in between the extremes of the social class scale.

Clements and Pickett (1957) also noted regional differences in stature and these differences tend to occur in most surveys, causing some confusion. In Grant and Hitchens (1953) survey of the heights and weights of students it was found that though the students were larger on average than the general population, the non-Welsh students were larger than the Welsh ones. There were no significant social class differences in the male students, but among the females the professional group were significantly larger than the manual group in both height and weight. The authors also quote the report that Cambridge undergraduates are on average 2 ins and 17 lbs greater in height and weight than National Servicemen, while students at the Welsh University exceeded the Servicemen's average by 1 in and 4 lbs. Thus it would seem that the association of increased stature and ability may continue into adult life.

The probability of regional differences in stature and growth patterns must be taken into account when considering comparisons of samples from different regions of the country. Acheson and Fowler (1964) compared intergeneration differences in a South Wales manual worker group and an upper income group from London. In fact it was predicted that both groups of offspring would become significantly taller than their parents, but the London boys were taller than the Welsh boys. Later Ashcroft and fellow workers (1967) found stature differences between two Welsh communities living only 15 miles apart. In this case it was found that miners tended to be shorter and lighter than rural workers. The rural women were taller than the women in the mining community, but there was a tendency for the latter group to become heavier in later life. However this type of difference must be dependent on the type of culture from which the samples are drawn. Ashcroft and his fellow workers in 1966 found that in Jamaica the urban males tended to be taller than the rural males.

Another measure of success is that of social mobility. This factor was found to be associated with a number of physical variables by Cliquet (1968). He found that the upwardly mobile men in his Flemish sample were larger, healthier and more intelligent than the remaining sample. They tended to mature earlier, but had less bone and muscle development than the downwardly moving sample.

Very few surveys have considered variables other than height and weight. Female foot size was investigated by Manning (1955). He found that the professional group had slightly larger feet than the rest of the women. However the small size of this group meant that this trend could not be tested. He also noted slight regional differences, with northern women having shorter feet.

Further useful information has been derived from groups who are issued with uniforms for their work. Morris and co-workers (1956) noted that the uniform records showed a difference in shape between conductors and bus drivers. Previously Morris and co-workers had found that men in physically active jobs were less likely to suffer a coronary artery attack than those in sedentary jobs (1953). Morris and Raffle (1954) found that the recovery rate after a coronary was greater in bus drivers than conductors. Morris (1959) quoted a list of occupations with an above average death rate from cardiovascular diseases. This included radio operators, priests, doctors and scientists and musicians.

Heady and co-workers (1961) noted that the sudden death rate from coronary heart disease was one third greater in conductors than bus drivers. The possibility that this difference was an effect of the job difference was investigated by Oliver (1967). He found that the men selected as drivers were significantly taller and heavier than those selected as conductors. A parallel difference between postal van drivers and postmen was noted by Oliver in 1969.

Though it is possible that men of certain types of physique tend to select certain types of occupation it is probable that there will be some effect due to the chosen occupation. Montegriffo (1968) found that many of the staff of B.P. were overweight, and Richardson and Pincherle (1969) found that a sample of British businessmen were on average 8 lbs overweight. In Khosla and Lowe's sample (1967) the senior staff were heavier than the wage earners, but the authors suggest that this difference may be due to a stature difference rather than obesity.

From these reports it can be concluded that there are significant differences in height and weight in the adult population. It may be that these differences are associated with occupation rather than with social class, as each of these classes contains a broad spectrum of types of occupation. However it cannot be decided from the present evidence whether there is self selection for type of occupation according to physical type, or whether physical changes occur as a result of the job type. It is probable that both situations occur.

5R.6 Other Environmental Factors Affecting Growth in Children

It would be an over-simplification to assume that their father's occupation is the only factor which affects growth in children. In fact a complex of factors act together to give the total environmental effect. Diet must be very important in this context. Berry and Cowin (1954) have shown that the weights of schoolboys were directly proportional to the standard of their diet. This relationship was present in both a grammar school sample and a secondary modern sample. It is also notable that Topps and co-workers (1970) found that the children of working mothers were on average heavier than those of non-working mothers. It might have been expected that children of a working mother might be more likely to receive an inadequate diet, but it would seem that the extra income tends to provide dietary improvements.

Family size is another factor which affects growth (Bransby et al 1946), though Maxwell (1953) noted that although the better-off children tended to be larger at all family sizes, there was still an association between the child's size and the number in the family. Grant (1964) has shown that there is a tendency for successive children of large families to be smaller, though this trend is not universal. He suggests that this may be the result of dietary changes as the number in the household increases. This successive reduction in size was also noted by Scott (1961) who also found that girls from large families tended to be late in maturing. In 1962 Scott noted that intelligence test scores showed the same pattern of decreasing with increasing family size. In contrast to this data on family size, Maxwell (1953) found that the children of older mothers tended to be taller and heavier. As the later born children of a family will also be the children of older mothers this result is difficult to comprehend, but it seems likely that there is a group of mothers who beget small families at a later age than average. Record et al (1969ab) noted that IQ scores were inversly related to birth order and maternal age, but not to birth weight.

Under inadequate housing conditions an increase in family size leads to an increase in overcrowding. Grant (1964) has suggested that this may account for the decrease in size of successive children of the family. Both Maxwell (1953) and Scott (1961) found that overcrowding led to a decrease in the height and weight. Craig (1963) attempted to isolate the various environmental variables involved in affecting the heights of Glasgow boys. He found that heights varied by social class, but within each class there were effects depending on the area within the city. Within social class groups size varied with overcrowding, but if the housing was a constant factor the boys' heights were associated with their social class group.

Two major factors affecting the growth of children are health and nutrition. The effects of war time deficiencies were noted by Grenlich (1951) in Guam, and Ellis (1945) in Belgium. A longitudinal study by Howe and Schiller (1952) showed that the general trend of increasing size is retarded during times of war, drought or economic depression. Hewitt et al (1955) have suggested that even minor maladies will affect the eventual adult skeletal height, though Prader et al (1963) noted that children whose growth has been retarded have a phase of accelerated 'catch-up growth' when conditions become favourable. However Spies et al (1959) found that the provision of a nutritional supplement for undernourished adolescents failed to change their skeletal maturation, whereas preadolescents showed an increase in growth. Mackenzie (1944) found that a greater proportion of children classified as intellectually 'bright' were receiving nutrition classified as excellent than were those classified as slow. Less intelligent children also showed a greater incidence of minor maladies such as infection of the upper respiratory tract and skin. It is also interesting to note that Shuttleworth (1940) found that growth in a sample of girls was significantly greater in certain 'good' years.

From these previous results it was seen that a full investigation of the effects of social class on metric variables must take into account a large range of possible complicating factors. Such a survey should include data on family size, accommodation, diet, number of sibs, position in family and parents' ages. Unfortunately in the planning stage of the present survey it was realised that requesting such a large volume of personal details from the subjects would result in multiple refusals. Even asking for details of fathers' occupation and parents' birthplaces provoked hostile reactions from some school authorities. It was therefore decided that further probing into environmental backgrounds could not be attempted.

5R.7 Differences in Neo-natal and Post-natal Environment

The size and health of the mother in addition to the post natal environment all contribute to the prospects of survival and health for the child. Morris and Heady (1955) and Morris (1959) report that the levels of neo-natal and post-natal mortality of children were higher in the lower social classes and in the manual occupational groups. Baird (1953) found that the proportion of small women (less than 5ft 1in) rose as the social class level declined. In a study of primigravidae he found that height and intelligence were both inversely related to social class, and also that the shorter women were often in poor health. Both poor health and small stature tended to give rise to premature births. Illesley (1955) noted high rates of premature births and obstetric deaths in SC IV and V women. Thompson (1959) suggests that the foetuses of shorter women have less survival chance than those of tall women, and this effect is noted in all social classes. He proposes that genetically short women are at a disadvantage in breeding in comparison with tall women. However he also notes that unmarried women tend to be taller than married women (Joint Clothing Council 1957, Karn 1958) which may indicate that tall women are at a disadvantage in finding a marriage partner. But there is also a tendency for tall girls to rise on the social class scale by marrying men of higher social class than their fathers. Thompson feels that this may be a process of genetic selection by social class. In a later paper (Thompson et al 1967) it was found that the differences between the social classes had become less marked, and it is suggested that the lower social classes are now becoming larger though the difference is not due to their attaining their full height at an earlier age.

A further obstetric factor that may be associated with social class is the effect of working during pregnancy. Stewart (1955) found that there were significantly more perinatal deaths and premature or small babies among mothers who worked. The rates were also raised among the wives of Social Class IV and V workers. However within a social class group there was little difference between the housewives and the workers, so it is possible that the difference was in fact only one of social class. Hewitt and Stewart (1952) noted that the babies of professional and administrative class parents tend to be larger than average because their parents are larger than average. However this difference is often evened out by the end of the first year owing to feeding differences. But Scarr (1969) has shown that babies which are large and fit at birth tend to obtain higher intelligence ratings at a later stage of development than small babies.

This effect may be due to intrauterine differences in nutrition.

McKeown and Record (1954) have noted that 'in man birth weight is inversely proportional to litter size'. Thus twins and multiple births tend to be of smaller size than the single born. Birthweight is correlated with both paternal and maternal height in the single born, but in twins the correlation with maternal height is increased and with paternal height it is decreased. Cowley and co-workers (1954) found that in the two years after birth the infant's weight was correlated with the height of the mother, but the father's height had little effect. This variation was independant of the duration of gestation, and the authors suggest that some maternal environmental factor influences the rate of foetal growth.

Though environmental factors play a very large part in determining the size of the individual the role of the genetic components is significant. Malina and fellow workers (1970) classified mating types according to whether the parents were small, medium or tall. The children of the marriages were then measured in height. The data showed that the children of two short parents were the shortest group, while the children of tall parents were the largest. It seems likely that large people have large children, as noted by Davenport (1917), for reasons of simple inheritance, given that the environment is favourable. It is when there are environmental factors opposing the hereditary tendencies that the situation becomes complex.

5R.8 Geographical Background and Metric Variables

In view of the Midland bias of the groups classified as

English and British it is surprising that any significant differences in metric variables were noted. There was very little variation between thr groups in foot length or width, nor in either of the body build indices. The significant difference between the English and Midland groups in the total sample results from the extreme height difference between these groups in the male sample. The fact that the largest female group was not the English but the British tends to discount any possibility of regional variation. The results for weight follow the same pattern, with the English males and the British females forming the heaviest single sex groups of the UK sample.

It is possible that these weight differences may reflect the association of parental origins and social class that was previously noted. But although the English male sample contained the greatest proportion of professional group boys, this group was even more fully represented among the English girls. Nor can the difference be fully explained by an extreme distribution of the SC-unknown girls into one parental origin group. The SC-unknown girls were both taller and heavier than the remaining classes, but they were distributed as 7 Midland, 3 English and 7 British. If the 7 SC-unknown girls included in the British group were of particularly large size this might in part account for the increased means of the British group.

It is however not impossible that these are regional differences in size. It must be remembered that Ashcroft et al (1967) found differences between two villages only 15 miles apart. Though the present data does not give any clear cut picture it may be that there are regional differences in the pattern of growth. Keddie (1956) found regional variations in the heights and weights of Scottish schoolchildren. (see 3S.5)

5R.9 Racial Differences in Metric Variables

The present survey data could not be expected to reveal any racial differences even if they were present owing to the inadequacy of the sizes of the West Indian and Asian samples. In general the differences between races have been reported to be slight. Ashcroft and co-workers (1966) found only inconsistent differences between children of African, Afro-European or European origins in Jamaica, though the Chinese tended to be lighter. The girls from more prosperous homes were taller than the London schoolgirls studied by Scott (1961). However Standard and his fellow workers (1966) found that the children of Barbados were smaller than those of Scott's survey, though they were larger than the African origin Jamaicans and the St.Kitts-Nevis-Anguilla children. The smaller stature of Chinese children in comparison with British children was confirmed by Chang and co-workers (1963). Frisch and Revelle (1969) compared an Asian group with a Latin American group. Both had approximately the same calorie intake, but the mean weight of the Latin American group was 9 lb greater than the Asian group.

5R.10 Associations between Metric Variables

Stone and Jones (1968) studied the intercorrelation of height, weight, foot length and foot width in male students. They found that all the six possible intercorrelations were significant at the 0.1% level. In the present survey there were fifteen possible intercorrelations and in addition each of these intercorrelations was examined in the two single sex samples as well as the total sample. The total sample showed significant intercorrelation in 11 of the possible 15, as did the male sample. Only 8 of the intercorrelations in the female sample showed significance. Huber (1969) also found ponderal index was significantly correlated with height. It might be expected that most physical measurements would show intercorrelation of some degree since they are dependant on the total body size. However in the active phase of growth the various body components tend to change in their relationships to each other. As previously mentioned there is a tendency for the limbs to enter the growth spurt period at an earlier stage than the main growth in length and weight. Similarly fat deposition has been shown to follow a complex pattern during the growth spurt. It is therefore possible that some of the correlations that lack significance in the present sample would be found to be significantly associated in an adult sample.

In the case of the two body build indices it would seem inevitable that these should show correlation with height and body weight. Yet these indices were derived in an attempt to isolate body build as a factor independant of height or weight. Ponderal index showed a very high level of correlation with height in all samples with correlation coefficients ranging from 0.83 to 0.96. However weight was only associated with ponderal index in the female sample, and then with a correlation coefficient of only 0.20. Thus the ponderal index is directly dependant on height, but it shows some independance from weight.

The obesity index showed a significant negative correlation with height in all three samples, the correlation coefficients in this case being between -0.26 and -0.29. There was a greater degree of correlation between weight and obesity index, where the correlation coefficient ranged between 0.49 and 0.80. The obesity index is therefore significantly associated with both height and weight, with a greater association with weight.

Since height and weight are significantly correlated, and the obesity index and ponderal index are significantly correlated with height and weight it is not unexpected that the two indices are correlated with each other.

But these close relationships would appear to diminish the importance of body build indices as independant factors. It is possible that the adolescence of the present sample is responsible for some difference in height/weight ratios, which has led to the present close association between the various factors.

The correlations of height with weight and foot length with foot width show that there is an association of growth of the body in length and width. The correlation of obesity and foot width probably indicated the effect of body weight in spreading the foot. There is also a correlation between foot width and height. Hill (1958) has suggested that increasing weight is a factor in increasing the width of the foot.

The use of the chisquare contingency tables revealed that it was possible to obtain differing results according to the handling of the data. In this case the more valid treatment of the data was to obtain correlation coefficients. Most of the intercorrelation values were in agreement with the chisquare results, but in some cases there was a discrepancy. Ponderal index was highly correlated with height in the male sample, but the chisquare revealed no significant association. However the chisquare tests showed a significant association between weight and ponderal index in males that has not been noted when the correlation coefficient had been used. (see 3S.7)

5R.11 Association of Hair Form and Metric Variables

No association of hair form with metric variables has previously been demonstrated. There was a tendency for the subject's degree of hair curl to increase in relation to their size. The trend was most marked among the males, where three metric variables showed a significant association with hair type, but the same trend occurs in the weight result for females. This association might have appeared as a result of the association of both hair type and size with social class. In both sexes there was an increased proportion of persons with curly or deeply waved hair in the more privileged social classes, and the relationship of increasing size to social class has just been discussed (see Section 5R.4). Another possibility would be that there were some geographical variations in hair type which could give rise to an apparent association between these factors, as there was some size variation between the geographical backgrounds. However there was no significant association between geographical background and hair type. (see 3S.8)

5R.12 Association of Skin Type and Metric Variables

Brues (1950) has noted an association between body build and freckling. This is in agreement with the results of the present survey, where skin type was significantly associated with height, weight and foot length in males, though there was only an association with height among the females. In general the smaller subjects showed a more intense pattern of freckling, though in fact the mean values for the lightly freckled group were sometimes less than those for the heavily freckled group. It is however uncertain whether the division of the subjects into two grades of freckledness has any validity. It is certain that there must be a large overlap between the two groups, owing to the variability of freckles produced by environmental effects.

With the added confirmation from Brues' results it would seem possible that there is a real association between skin type and body build. However it is also possible that differences in geographical origin are responsible for the apparent association, as skin type has been found to be associated with this variable. But the data on size and geographical origins shows that though the English boys were largest, there was little difference between the Midland and British boys. It may be that the British boys were smaller and more deeply freckled, while the Midland boys joined the non-freckled group. (see 3S.9)

5R.13 Association of Hair Colour and Height and Weight

There was a significant association of size, both height and weight, with hair colour, but this relationship was only present in the female sample. The fair haired subjects of both sexes tended to be lighter in weight than the dark haired subjects. Height was only associated with Munsell Chroma, but in this case the same trend was noted, with the shortest height group having the least intensely pigmented hair. It may be significant that hair redness in the present survey was found to be associated with skin type, skin type being also associated with metric variables. However the association of height and weight with skin type was more pronounced in the male sample, whereas the association of hair colour and weight is only present among the females. It may be that there is some general association of body size and pigmentation. (see 3S.10 and 3S.11)

5R.14 Association of Ponderal Index and ABO Secretor

There was a tendency for the ABO secretors to be more linear in body build than the non-secretors. This trend was only significantly different among the females, but there were also differences in the males. This sex difference could be caused by the majority of the girls having completed the growth spurt, whereas the boys were still in active growth. No such association of ABO secretor and ponderal index has previously been noted, but the secretor trait has been found to be associated with susceptibility to duodenal ulcer. From this it would seem that there are physiological differences between the secretor types, and it is possible that there could be differences in body build, or perhaps in growth pattern. (see 3S.12)

5R.15 Association of Ponderal Index and Hair Colour

Since weight was significantly associated with hair colour, and in females with ponderal index, it is therefore likely that the association of weight and hair colour in the present female sample is a reflection of the association of weight and hair colour. As previously stated there may be a general association between body build and pigmentation, though this result has not been shown in any survey except that of Brues (1950). (see 3S.13)

5R.16 Association of Height and Finger Length

It must be remembered that finger length is a variable that shows a considerable sex difference, with long ring finger being common in males and long index common in females. The reversal of height trends in the present survey means that boys showing the 'masculine' finger type are on average taller than those with the feminine finger type. But in the female sample the girls with a 'feminine' finger type were significantly taller than those with the 'masculine' finger type. It seems probable that development of the eventual adult finger type is associated with growth in general. Rosler (1957) has noted that there are finger type changes at adolescence. In this case it may be that those subjects whose tallness proclaims them to be advanced in the growth spurt are also advanced in their development of their adult finger type. (see 3S.14)

5R.17 Association of Metric Variables and Laterality Variables

No previous survey has noted association between metric variables and laterality factors. Yet the evidence of the present survey shows that in this particular sample there were many such associations. As the ten laterality activities themselves show a high degree of association with each other it would be expected that any metric variable associated with a laterality activity would show some degree of association with other laterality activities. This factor may account for the significant association of weight with eight of the ten laterality variables. However ponderal index, which is significantly associated with weight, is only associated with two laterality variables, and height is only associated with one.

There is no clear trend in the results that would lead to the association of size with either left or right laterality. The situation appears to differ in the two sexes, and it must be remembered that significant sex differences have been noted in several laterality variables. Only the ponderal index results show comparable influences in the single sex samples.

In both the associations of ponderal index with writing and with hammering the right handed subjects had a higher ponderal index than the left handed ones. There was consequently an increased percentage of left handers in the lower ponderal index classes of the divided range. This and the following associations might be indications of social class or other non-biological influence on handedness, as size has been shown to be associated with social class, and there were certain associations between laterality and school-type.

The height and kick comparisons are complicated by a sex difference in the maximum value class. Among the males the left-footed group were tallest, while the undecided laterality group in girls showed this characteristic. Nor were the left-footed girls second

second in tallness; they were in fact 1.2cm shorter on average than the right-footed girls. It is difficult to postulate a mechanism which would lead to such differences, but the significant sex differences in this character may play a part in this variation.

In almost all the associations of laterality characteristics with weight there was a sex difference in the pattern of the distribution of left-lateral subjects by weight. The median weight group showed an increased percentage of left dominant girls, but the percentage of left lateral males in this group was decreased relative to both the heavier and the lighter boys. This relationship holds in both sexes for card dealing, throwing a ball, using a racquet, using a hammer, threading a needle and kicking a ball, and for unscrewing a jartop in the female sample. Among the males the percentage of left handed in unscrewing a jartop increases with increasing weight. The association of weight and eye dominance showed a reversal of trends in the two sexes, the percentage of left eyed boys decreasing with increasing weight while the percentage of left eyed girls increased with this factor. There was no sex difference in eye dominance, so this cannot be associated with the result.

In the associations with weight other than eye dominance there was no clear pattern of greater weight in one group. The mean weights of the left (left plus undecided) and right dominant groups were often only slightly different. There were differences between the sexes in all the associations except card dealing and hammering, when the left handed group were heavier, and threading a needle where the right handed group were heavier. All the other associations showed one sex with left laterals exceeding right and one sex with the opposite result.

The general conclusion from these results is that the greatest proportions of the left lateral subjects appeared in the median weight group in females and the high and low weight groups in males. Both the height and ponderal index associations would seem to indicate that there is a tendency for the left dominant or ambidextrous subjects to be larger but less linear in body build than the right dominant subjects.

No previous association of metric variables and laterality have been noted. In this case the situation is complicated by significant sex differences in some laterality variables and metric variables, and it is possible that the association of certain variables with school type might have affected the result. School type was significantly associated with social class, and there were significant social class differences in metric variables. This suggestion is however made less probable by the lack of any significant association between social class and laterality variables. (see 3S.15a-l)

5S - General Discussion of the Survey as a Whole

5S.1 Introduction to General Discussion

Perhaps the most notable conclusion that can be drawn from the present project is that the relationships between the various genetic factors in human populations are extremely complex. In fact it appears that at the present level of knowledge each dimension added to the survey plan reveals new tracts of unexpected interrelationships.

It is important to bear in mind that the aim of the survey was to investigate the possibility of social class differences in genetic polymorphisms. In this context it is the significant associations of characteristics with social class, class group or school type which are of importance. However the presence of significant sex differences and variations between groups of different parental origin is also of interest. Where a trait has been shown to be influenced by one or more environmental factors other than those aimed at by the investigation, it may be necessary to qualify the original result. It is possible that, for example, a significant difference between parental origin groups for a particular trait could mask a real difference between school types. Conversely an uneven distribution of such parental origin classes within the school type groups might give false positive results.

5S.2 Assessment of the Possibility of False Positive Results

It is customary in handling biological data to use the 0.05 level of probability as the dividing line between statistical significance and non-significance. However such a choice means that approximately one in twenty of the comparisons made will give a significant result which does not represent a real association but an extreme sampling variation. This possible source of error has been noted by Morton et al (1966), who suggest that where less than 5% of the total comparisons show significance, the results should be rejected.

This is an extreme view as it is not possible to distinguish the false positive results from genuine associations, particularly where there are very many positive associations. It would seem more logical to accept all positive associations but also accept the possibility of their unreality, at the level of probability in question.

In the present survey it was decided to test what proportion of associations had given positive results. There were various factors which tended to complicate and possibly invalidate this procedure. The basic question was whether two different comparisons of the same data should be counted as a single comparison for the purpose of counting the total of positive associations. This problem occurred where a variable was used in statistical tests in two forms. For instance skin type occurred both as a two category variable (freckles absent/present) and a three category variable (freckles absent/few/many). In practice it was decided to use totals formed by accepting any significant association between two variables as indicating a positive association.

A further complication is that the laterality variables and the divided metric variables might legitimately be expected to show a higher frequency of significant interrelationships, and so it is uncertain whether the results of such comparisons should be included in the general total. There were also significant differences between the single sex samples and the total sample, so it would seem necessary to examine the frequency of significant results within each sample separately. It is also important that much of the secondary examination of data was confined to associations which had already been shown to be significant in one subsample. Thus it is felt that the inclusion of some of the Kolmogorov-Smirnov test results and the 't' test comparisons of metric and non-metric variables may be invalid in the total of significant results.

It was decided to consider the totals of significant associations in relation to various sub groups of potential associations. At this point it is therefore necessary to summarise the results of the survey in these terms.

5S.3 Restatement of Positive Results

The total list of variables included in the survey can be placed in four groups: background (parental origins, school type, sex, social class); metric variables, laterality variables and the remainder of non-metric variables. Using these groups the total of possible comparisons can be divided into ten categories, for ease in discussion. The ten categories are formed by six categories of combinations between groups and four categories of intra-group comparisons.

The comparisons of background and metric variables were tested by means of 't' tests. Each of the six metric variables gave rise to a total of 17 't' comparisons in the male, female and total samples for the school type, social class, class group and parental origin comparisons. In addition there were six possible sex difference comparisons. It was found that 30 of the 312 possible comparisons were significant at the 0.05 level; a total of 9.9%.

In the background and laterality comparisons it was found that five variables showed sex differences, and two showed an association with social class in the male sample. The total number of possible associations in this case was 100, there being potential association of sex, social class and parental origin with each of the 10 laterality variables, with possible sex differences in the total sample. In the single sex samples the sex association is omitted. It will be seen that the finding of 7.0% significant results exceeds the 5% expected by chance.

The comparison of background variables and non-metric traits is complicated by the division of some variables into various versions as previously mentioned. If each trait is considered as representing only one possible factor in the comparisons there are 13 traits in the total and female samples, and 14 in the male sample where colour vision is added. This gives a potential total of 52 associations for the total sample, 39 for the female sample and 42 for the male sample. It was found that 20 of the possible associations were significant at the 0.05 level, which represents 15.0%.

In the metric and non-metric variable comparisons the total sample data was not examined owing to sex differences. This gave a total of 65 possible associations in the female sample and 70 in the male sample as obesity index was not included. It was found that 10 of these comparisons were significant which gives a value of 7.4% for the frequency of significant variables.

The comparison of metric variables and laterality variables also concentrated on the single sex samples and omitted obesity index. This gave a possibility of 50 associations in each sex. A total of 13 (13%) of these associations were significant at the 0.05 level.

The total of possible associations in the comparison of laterality variables and non-metric variables is 400, being 140 for the male sample and 130 for each of the female and total samples. Only 13 of these(3.0%) are significant at the 0.05 level of probability. Closer examination of the data shows that 8 (6.1%) of the total sample comparisons are significant, so it is possible that sample size may be important in this group of variables.

It would be expected that some significant association within the background variable group would appear, as educational level is generally known to be associated with social class. There is a possibility of 12 associations within the group, and it was found that of these 7 (58.3%) are significant.

The interrelationships between metric variables were tested both as continuous variables by calculation of the correlation coefficients, and as discontinuous variables by calculation of chisquare values. In the latter case obesity index was omitted. This gives a possibility of 15 significant correlation coefficients for each of the three samples, and 10 possible chisquare results for each single sex sample. It was found that 17 (85.0%) of the chisquare results were significant at the 0.05 level and 32 (17.1%) of the correlation coefficients were significant.

The possible interrelationships of the ten laterality variables give rise to 45 pairs of activities in each of the three samples. Of this total 127 (93.3%) were significant, the majority of these being very highly significant.

The Munsell hair colour results have been omitted from the calculation of the total possible interrelationships with the non-metric group as it was felt that these variables were added at a secondary stage. This leaves 78 possible associations in the female and total samples and 84 possible associations in the male sample. It was found that 34 (14.2%) of these possible associations were significant at the 0.05 level.

From the above data it is evident that the overall frequency of significant results obtained in the present survey is far greater than that expected by chance alone. It must be concluded that many of these results represent real associations between pairs of characteristics, but as previously stated it is not possible to determine which results are merely due to sampling effect.

A further complication in the consideration of the significance of the results is the possibility of spurious correlation of associations. Where two independant variables are both significantly associated with a third variable it is probable that an apparent association between the former pair of variables will be found. An attempt has been made to allow for this possibility in the previous discussion sections. Whenever it has been noted that a trio of variables are showing an association this fact has been emphasised. However as with the case of the associations due to chance it is not possible at this stage to determine which variables are linked in fact and which are showing a spurious association.

5S.4 Sex Differences in Survey Data

In the face of such a large volume of complex and sometimes contradictory data it is tempting to place more reliance on those associations which can be seen to hold valid in both single sex samples and the total sample. This would be a reasonable attitude only if it were certain that the traits under consideration were not subject to any form of sex influence. This is not the case, as several of the traits under study have previously been shown to exhibit some form of sex difference. Ear lobe type, finger length, mid-digital hair and PTC tasting have all been quoted as showing significant sex differences, though the data for PTC is not clear. Yet in the present survey significant differences were found in ocular defect, hair colour, hair line and half the laterality variables, while no difference could be demonstrated in PTC tasting and mid-digital hair types.

If characteristics are found to show evidence of being sex influenced in some degree it is perhaps not unexpected that these traits should also show differences in their pattern of association with other characteristics. It would be expected that an association between two sex influenced characteristics would result in the positive association of the more commonly male versions of the variants, but in practice it is found that this does not occur.

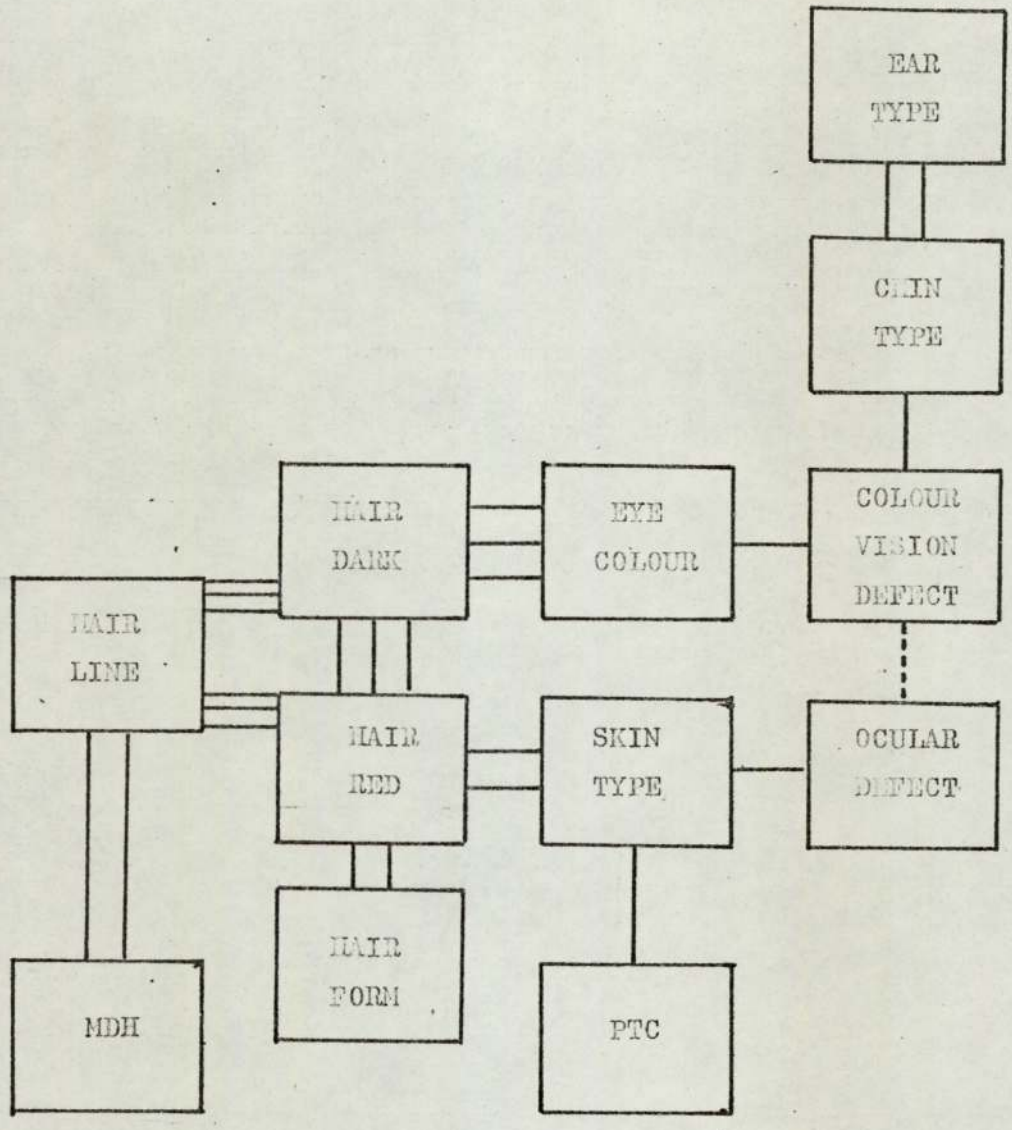
A still more complex situation is found where the two single sex samples show opposing trends with regard to some characteristic. This is a feature which would not become apparent unless a mixed sample were analysed in terms of single sex groups. This relationship is exemplified by the laterality by school type comparison, where the male sample showed an excess of left handed males in the non-selective group while the females showed excess left dominant subjects in the selective group. This opposition of trends gave non-significant results in the total sample, effectively masking a significant difference in the male sample.

Despite these complications it can be shown that a similar nucleus of interrelated traits is evident in both single sex and total samples (see figs 21abc). It is not possible to express the relationships adequately in terms of a block diagram, as a three dimensional model would be more appropriate, nor is it possible to include all the possible significant associations. It is also reassuring to note that the present survey has not failed to demonstrate the well known associations of hair darkness with hair redness and eye colour, and hair redness with skin type.

5S.5 The Effect of Puberty on the Present Sample

It must be admitted that the age range of the present sample was not ideal for the purpose of the present survey. In the age group 14-15 the majority of the girls studied would have passed their most active phase of growth while most of the boys would still have been at the growth spurt period. This difference has meant that the possible effects of puberty could not be discounted in various associations, whereas the use of a fully adult sample would have enabled less qualified conclusions to be put forward. However in defence of the present sample it can be said that it enables the

Fig. 21a. Diagrammic representation of significant associations between non-metric variables in male UK sample



Relative distance between blocks not relevant.

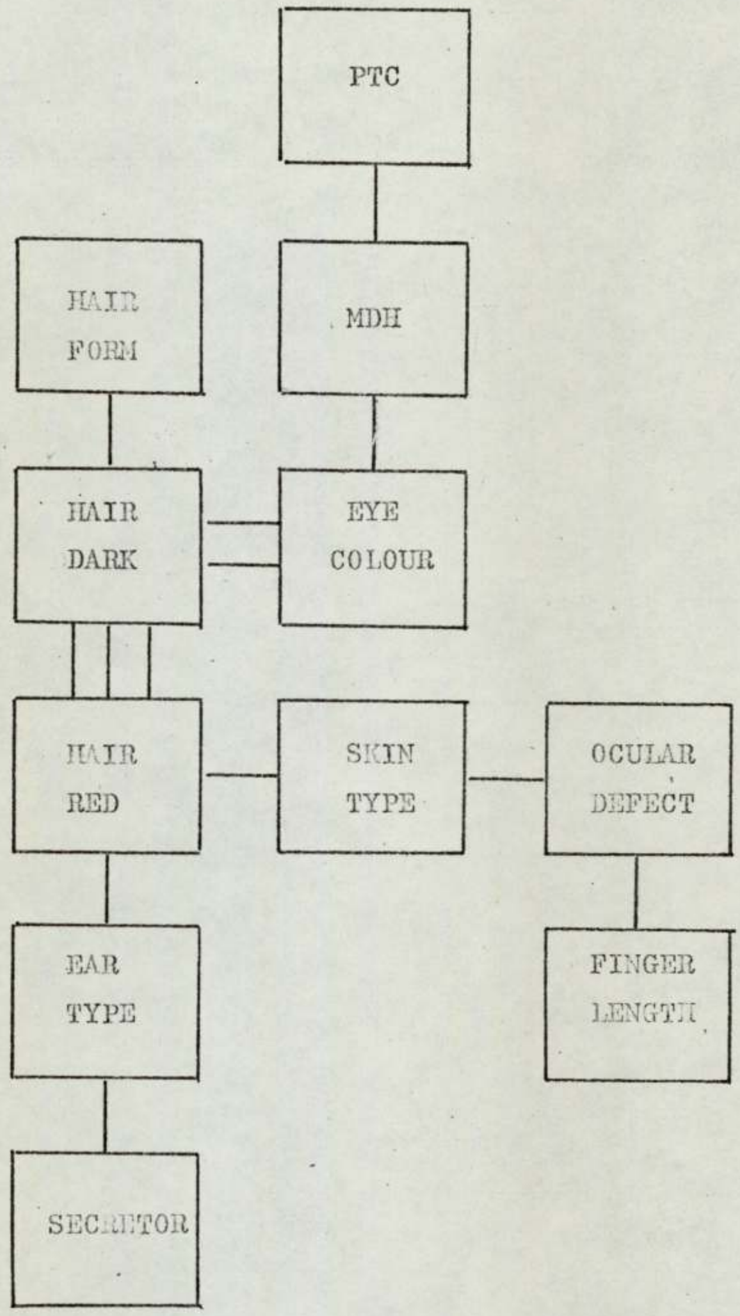
Significance level indicated by number of connections between blocks;

≡ = $p < 0.001$

= = $0.01 > p > 0.001$

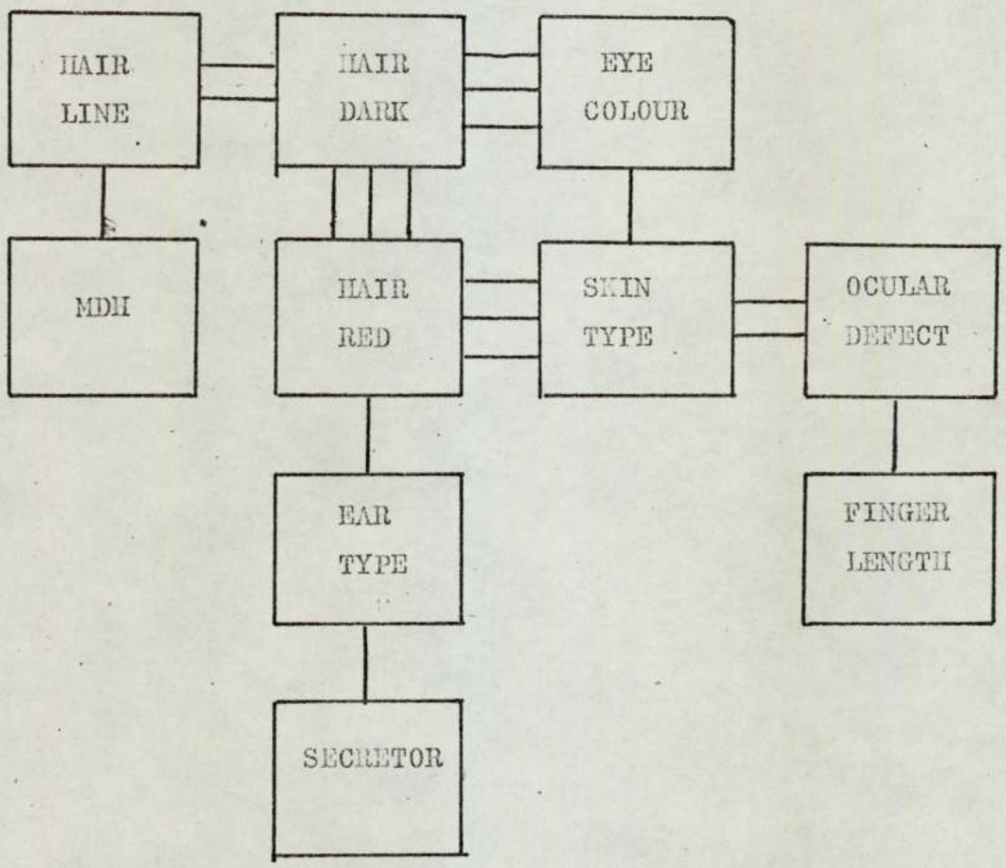
— = $0.05 > p > 0.01$

Fig. 21b. Diagrammatic representation of significant associations between non-metric variables in female UK sample



Significance, etc, as Fig. 21a.

Fig. 21c. Diagrammic representation of significant associations between non-metric variables in total UK sample.



Significance, etc, as Fig. 21a.

present survey to produce new data of the frequencies of polymorphic variables in an adolescent British sample. As previously explained it proved impossible to obtain an adult sample, and in using a sample of schoolchildren it was felt advisable to leave the point of study as late as possible in order to facilitate the survey situation. It is uncertain whether a slight reduction in the age of the sample would have clarified the situation with regard to puberty, and examination of 11 or 12 year olds would have made the school classification less valid because of the 13+ examination.

It was not the purpose of the present sample to collect data on the possible physical differences between the native British population and the immigrant groups. Such comparisons as were possible with the small samples available gave no significant differences between the population groups. Any further study in this context would need to consider the possibility of differences in pubertal age between the various population groups.

5S.6.

The Value of the Twin Survey in the Present Investigation

Once again it must be said that the present twin survey was of necessity limited both by the time and funds available. The need to obtain a sample of twin comparable with the adolescent main survey sample means that any estimates of heritability are specialised, relating to the particular age group under study. The factor is of particular relevance in consideration of those traits where the heritability as estimated in the present survey proved to be far less than the general expectation. In particular mid-digital hair and PTC tasting fell short of their expected levels of heritability, and it is interesting to note that both these characteristics are often found to exhibit significant sex differences though neither showed this effect in the present survey. It may be that the relatively small sample size in the twin survey was responsible for some exaggeration of intrapair variations, and it might have been advantageous to collect a large enough sample to give single sex estimates of heritability. This is particularly the case where characteristics studied have been noted as showing sex differences.

The present twin survey results for the heritabilities of the metric variables (with the exception of foot width) were extremely high. Though the results are comparable with others previously noted for young adults it is possible that the heritability values in the metric variables have been exaggerated by factors determining the growth spurt. Furosho (1968) noted that there is a transitory decrease in correlation for stature in twins at the most rapid period of growth. He suggests that the pattern of growth is under the control of genes which may show some independance from those controlling the eventual stature. In this case the metric differences between dizygotic twins may be maxminized at puberty, while monozygotic twins would have a greater probability of being concordant for their periods of maximum growth. Thus adolescent dizygotic twins may show differences in metric variables owing to differences in growth pattern which will not persist into adult life.

On the credit side it can be said that the present twin survey, despite its shortcomings, has provided concordance data for a number of characteristics not previously examined by this method.

It is felt that the imperfections of the methods of calculating heritability may undermine the validity of this concept, but whatever measure is taken to attempt to separate the genetic and environmental components of a characteristic the present survey data remains of value. If time had allowed it would have been hoped to use other methods of analysing the twin data, but unfortunately this was not possible.

5S.7 Significant Association with Social Class and School Type

In discussion of the various aspects of the results it is important not to overlook the stated aims of the project which were to test the hypothesis that genetic social class differences can be demonstrated. School type variations may legitimately be included in this section as an indication of the individual child's own potential success standing in future.

Many previous surveys have demonstrated social class differences in metric variables, and so it is not surprising that the present survey should find significant differences in this field. In general the larger individuals were found to represent the more privileged social class, and so the effects of environmental differences must be considered, though the literature tends to show that the social class differences persist given constant environmental conditions.

It is of particular interest that the present survey has been able to demonstrate significant associations of social class and school type with laterality and non-metric variables. The laterality variables may be subject to environmental pressures, but it is unlikely that characteristics such as hair form and chin type can be influenced by such environmental effects.

It is true that only a minority of the non-metric and laterality variables were shown to be associated with the social environmental factors. It is also possible that these results may represent some peculiarity of the present sample of individuals. Yet it must be felt that these results indicate that genetic differences between social class groups do exist and can be demonstrated.

5S.8 Associations Not Involving Social Class

Another valuable aspect of this survey has been the collection of a large volume of data on the frequencies of various polymorphic characteristics, and the examination of associations between these characteristics. Among other variables included was that of parental origin, and it was surprising to note that hair redness and freckles showed a significant association with this character, even though the composition of the regional samples was strongly biased towards the Midland region.

Though many of the characteristics included in the survey were of an apparently trivial nature it would seem probable that these characteristics represent the outward manifestations of basic genetic differences between individuals which may represent differences in fitness. Ford (1964) has put forward the view that the alternative forms of genetic variables must have reached their current frequencies because the genetic units controlling them are of basic importance to the organism. It follows therefore that any polymorphism which is represented in a stable population to any notable frequency must have reached that frequency because of some adaptive significance related to the variant.

This argument may also be applied to the association of social class and physical variables. If a genetic marker such as chin type were the outward manifestation of some factor giving an increased chance of social success this would explain the presence of such associations. It is known that blood groups can be associated with susceptibility to certain diseases, so it is not unreasonable to propose that various genetic markers could be associated with success abilities.

5S.9 Conclusion

In effect the present investigation has acted as a sieve, screening a wide range of genetic polymorphisms for their potential use as markers of social class success, and investigating the relationship between the polymorphic characteristics.

At the present level the investigation is comparatively crude, and it is realised that many valid associations may have been masked by the techniques used, while some of the positive results may be artifacts. The main value of the project is then in providing much basic data and a wide range of starting points for future investigators.

6 SUMMARY OF CONCLUSIONS

(a) It has been shown that social class groups differ significantly in the frequencies of certain polymorphic traits, and in their distribution of metric traits. (see tables H5, F14)

(b) It has been shown that school type groups also differ significantly in the frequencies of certain polymorphic traits. (see tables G11, F14)

(c) Significant sex differences have been found in various characteristics, including both metric and polymorphic variables. (see tables H8, G11, F14)

(d) A small number of the traits studied showed significant differences according to the regional origin of the subjects within Britain. (see tables H6, F14)

(e) A large number of the traits studied were found to be significantly associated with other physical variables under study. Though some of these associations could have been logically expected (e.g. associations between height and weight) many new relationships have been reported. (see appendixes I,J,K,L,M,N)

(f) The data provides basic frequencies for a wide range of genetic variables in this British sample of limited age range. (see Appendixes F,G,H)

(g) A small scale twin study has provided estimates of heritability for the traits under study. (see Appendix O, table O7)

(h) Various experimental methods have been tested and discussed, with new procedures being devised in some cases. (see section 2)

(i) A specialized computer program to handle the survey data was written by use of the MVC system. (see Appendix B)

(j) Very small samples of West Indian and Asian immigrant children were found to show no significant differences from the UK population in metric variables. (see table H9)

(k) A comprehensive review has been made of the previous work in this field, and the results of the present survey have been discussed with reference to these reports.

REFERENCES

The references are arranged alphabetically by name of author.

Multiple references by the same author are arranged in date order.

If the same individual occurs both as sole and joint author, the sole author papers precede the papers in joint authorship. The order of the papers in joint authorship is determined by the alphabetical order of the names of the second authors.

e.g. Smith, A. (1952)
Smith, A. (1960)
Smith, A. & Jones, B. (1955)
Smith, A. & Williams, C. (1953)

Journal titles are abbreviated according to the World List of Scientific Publications 1900 - 1960 (pub. Butterworth 1965), and the British Union catalogue of periodicals 1960 - 1968 (pub. Butterworth 1970), 1969 (pub. Butterworth 1969) and 1970 (pub. Butterworth 1970).

References are specified by the following sequence:

Author(s) (date)
Journal title volume no. first page no.
Title.

Abbie, A.A., & Ras, P.D.P. (1965)

Hum. Biol. 37 162

Hairy Pinna in Australian Aborigines.

Abramson, E., & Ernest, E. (1954)

Acta Pediat. 43 235

Height and weight of schoolboys at a Stockholm secondary school, 1950, and a comparison with some earlier investigations.

Acheson, R.M. & Dupertuis, CW. (1957)

Hum. Biol. 29 167

Physique and Skeletal Maturation.

Acheson, R.M., & Fowler, G.B. (1964)

Br. J. prev soc. Med 18 25

Sex, socio-economic status and secular increase in stature.

Acheson, R.M., & Hewitt, D (1954)

Br. J. prev. soc. Med 8 59

Oxford Child Health Survey: stature and skeletal maturation in the pre-school child.

Adam, A. (1969).

Soc. Biol. 16 197

A further query on colour blindness and natural selection.

Agrawal, A. (1965).

East. Anthrop. 18 100

Mid-phalangeal hair among the Muslins of Andaman.

Agrawal, H.N. (1966)

East. Anthrop. 19 107

A study on ABO blood groups, PTC taste sensitivity and mid-phalangeal hairs among Burmese immigrants of the Andaman Islands.

Ainsworth Harrison, G., Owen, J.J.T., (1964)

Ann. Hum. Genet 28 27

Studies on the inheritance of human skin colour.

Åkesson, H.O. (1959a)

Acta Genet. med. Gemell 8 431

Taste deficiency for phenylthiourea in Southern Sweden.

Åkesson, H.O., (1959b)

Ann. hum. Genet. 23 262

Taste sensitivity to phenylthiourea intuberculosis and diabetes mellitus.

Allison, A.C. (1951)

Man 51 119

A note on taste blindness in Kenya Africans and Arabs.

Allison, A.C. & Nevanlinna, H.R. (1952)

Ann. Eugen. 17 113.

Taste deficiency in Lappish and Finnish populations.

Allison, A.C., & McWhirter, K.G. (1956)

Nature 178 748

Two unifactorial characters for which man is polymorphic.

Anderson, M., Blais, M.M., & Green, W.T. (1956)

Am. K. phys. Anthrop 14 287

Growth of the normal foot during childhood and adolescence.

Anderson, W.F., & Cowan, N.R. (1966)

Br. J. prev. soc. Med 20 141

Hand grip pressure in older people

Annett, M., (1967)

Q.J. exp Psychol. 19 327

The binomial distribution of right, mixed and left handedness.

Annett, M., (1964)

Nature 204 59

A model of the inheritance of handedness and cerebral dominance.

Ardashnikov, S.N., Lichtenstein, E.A., Martynova, R.P., Soboleva, A.V., & Postnikova E.N. (1936).

J. Hered 27 465

The diagnosis of zygosity in twins.

Arnow, L.E., (1938).

Biochem. J. 32 1281

The acid soluble pigment of human red hair.

Ashcroft, M.T., Henage, P. & Lovell, H.G. (1966)

Am. J. phys. Anthrop. 24 35

Heights and weights of Jamaican schoolchildren of various ethnic groups.

Ashcroft, M.T., Hay, J., Lovell H.G. & Miall, W.E. (1966)

Br. J. prev. soc. Med. 20 22

Heights and weights of adults in rural and urban areas of Jamaica.

Ashcroft, M.T., Lovell, H.G., Miall, W.E. & Moore, F. (1967).

Br. J. prev. soc. Med. 21 159

Heights and weights of adults in rural and industrial areas of South Wales.

Ashley, D.J.B.,(1968).

Hum. Biol. 40 517

Welshness and Disease.

Ashley, D.J.B. (1969a)

J. med. Genet 6 180

Welshness and fertility.

Ashley, D.J.B., (1969b)

J. med. Genet. 6 70

Oesophageal cancer in Wales.

Ashley, D.J.B., (1969c)

J. med. Genet. 6 76

Gastric cancer in Wales.

Astwood, E.B. (1943)

J. Am. med. Ass. 122 78

Treatment of hyperthyroidism with thiourea and thiouracil.

Astwood, E.B., Greer, M.A. & Ettinger M.G. (1949)

Science, N.Y. 109 631

The antithyroid factor of yellow turnip.

Auerbach, C. (1962)

The Science of Genetics

pub. Hutchinsons.

Azevedo, E., Kreiger, H., Mi, M.P. & Morton, NE. (1965)

Am. J. hum Genet. 17 87

PTC taste sensitivity and endemic goiter in Brasil.

Baird, D., 1953.

Eugen. Rev. 45 151

Health and physique of mothers in various social groups.

Baldwin, W.K., (1964)

Am. J. Optom. 41 513

The relationship between the axial length of the eye and certain other anthropometric measurements of myopes.

Barker, D.J. (1967)

<u>Q.J. exp Psychol</u>. <u>19</u> 334

Left-right differences in auditory perception of verbal and non-verbal material by children.

Barnicot, N.A. (1949)

<u>Ann. Eugen</u>. <u>15</u> 249

Taste deficiency for PTC in Africans Negroes and Chinese.

Barnicot, N.A. (1952)

<u>Ann. Eugen</u>.<u>17</u> 211.

Red Hair in African negroes: a preliminary study.

Barnicot, N.A. (1956a)

<u>Nature 177</u> 528

The pigment, tricosiderin, from human hair.

Barnicot, N.A. (1956b)

<u>Ann. hum Genet</u>. <u>21</u> 31

The relation of the pigment tricosiderin to hair colour.

Barnicot, N.A. (1963)

<u>Curr. Anthrop</u>.<u>4</u> 117

Racial taxonomy

Barnicot, N.A., Birbeck, M.C. & Cuckow, F.W. (1955)

<u>Ann. hum Genet</u>. <u>19</u> 231

The electron microscopy of hair pigments.

Barnicot, N.A., Harris, H. & Kalmus, H. (1951)

<u>Ann. Eugen</u>. <u>16</u> 119

Taste thresholds of a further eighteen compounds and their correlation with PTC thresholds.

Barton, W.H., & Hunt, E.E. (1962)

Hum. Biol. 34 254

Somatotype and adolescence in boys

Basu, A. (1965)

Acta Genet. med. Gemell. 14 317

Hairy ears among the Pahira

Basu, A. (1967)

Acta genet. Statist. med. 17 158

The frequency of midphalangeal hair in some population groups of Maharashtra (India).

Beach, S.A. (1953)

Heredity, Lond. 7 401

The frequency of taste blindness in Welsh populations.

Becker, B. & Morton, W.R. (1964)

Archs Ophthal. N.Y. 72 323

Phenylthiourea and glaucoma

Beckman, L, & Böök, J.A. (1959)

Hereditas 45 215

Distribution and inheritance of mid-digital hair in Sweden.

Beckman, L., & Elston, R (1962).

Hum. Biol. 34 99

Data on bilateral variation in man: handedness, hand clasping and arm folding in Sweden.

Beiguelman, B (1964a)

Acta Genet. med. Gemell. 13 190

Taste sensitivity to phenylthiourea among patients affected with both tuberculosis and leprosy.

Beiguelman B. (1964b)

Acta Genet. med. Gemell. 13 193

Taste sensitity to phenylthiourea and leprosy.

Beiguelman, B. (1964c)

Acta Genet. med. Gemell. 13 197

Taste sensitivity to Phenylthiourea and menstruation.

Beiguelman, B. & Marques, M.B. (1964)

Acta Genet. med. Gemell. 13 200

Taste sensitivity to phenylthiourea and drugs with anti-leproic effect.

Belcher, S.J., Greenshields, K.W. & Wright, W.D. (1958)

Br. J. Ophthal. 42 355

Colour vision survey using the Ishihara, Dvorine, Bostrom and American Optical Hardy-Rand-Ritter tests.

Bellamy, R. (1930)

Am. J. phys. Anthrop. 14 75

Measuring hair colour

Belmont, L. & Birch, H.G. (1963)

Child Dev. 34 257

Lateral dominance.

Benton, A.L. & Menefee, F.L. (1957)

Child Dev. 28 237

Handedness and right-left description.

Berg, J.M. & Stern, J. (1958)

Ann. hum. Genet. 22 370

Iris colour in phenylketonuria.

Bernheim, F. & Bernheim, M.L.C. (1942)

J. biol. Chem. 145 213

The action of PTC on tyrosinase.

Bernstein, M.M. & Burks, B.S. (1942)

J. Hered. 33 45

The incidence and Mendelian transmission of mid-digital hair in man.

Bernstein, M.M. (1949)

J. Hered. 40 127

The mid-digital hair genes. Their inheritance and distribution among the white race.

Bernstein, M.M. & Burks, B.S. (1948)

J. Hered. 39 93

A note on iris rim color and width

Berry, H.K., Dobzhansky, T., Gartler, S.M. Levine, H & Osborne, R.H. (1955).

Am. J. hum. Genet. 7 93

Chromatographic studies on urinary excretion in MZ and DZ twins.

Berry, W.T.C. & Cowin, P.C. (1954)

Br. med. J. 1 847

Conditions associated with the growth of boys 1950-1.

Bhasin, M.K. (1969)

Human Hered. 19 506

Ear lobe attachment among the Nevas of Nepal.

Bhattacharya, D.K. (1964)

Acta Genet. med. Gemell 13 159

Tasting of PTC among Anglo-Indians of India.

Billewicz, W.Z., Kemsley, W.F.F. & Thomson, A.M. (1962)

Br. J. prev. soc. Med. 16 183

Indices of adiposity.

Blais, M.M., Green, W.T. & Anderson, M. (1956).

J. Bone Jt. Surg. 38A 998

Lengths of the growing foot.

Blakeslee, A.F. (1932)

Proc. natn. Acad. Sci. U.S.A. 18 120

Genetics of sensory thresholds: taste for phenylthiocarbamide.

Blakeslee, A.F. & Salmon, M.R. (1931)

Eugenl News 16 105

Odor and taste blindness

Blincoe, H. (1962)

Am. J. phys. Anthrop 20 45

Significant hand types in women according to relative lengths of fingers.

Bonné, B. (1966)

Am. J. phys. Anthrop. 24 NS 1

Genes and phenotypes in the Samaritan isolate.

Bonnevie, K (1924-1925)

J. Genet. 15 1

Studies on papillary patterns of human fingers.

Boorman, K.E. & Dodd, B.E. (1966)

An introduction to blood group serology

3rd Edition. J.A. Churchill Ltd.

Boyd, W.C. (1950)

Science, N.Y. 112 153

Taste reactions to antithyroid substances.

Boyd, W.C. (1951)

Psychol. Bull. 48 71

Taste blindness to phenylthiocarbamide and related compounds.

Boyd, W.C. (1962)

<u>Acta Genet. med. Gemell</u> <u>11</u> 269

Natural selection and heredity.

Boyd, W.C. & Boyd, L.G. (1937)

<u>Ann. Eugen.</u> <u>8</u> 46

Sexual and racial variations in ability to taste PTC with some data on inheritance.

Boyd, W.C. & Shapleigh, E (1954)

<u>Blood.</u> <u>9</u> 1195

Separation of individuals of any blood group into secretors and non-secretors by use of a plant agglutinin (lectin).

Bramwell, B.S. (1923)

<u>Eugen. Rev.</u> <u>15</u> 480

Observations on racial characteristics in England.

Brand, N (1963)

<u>Ann. hum. Genet.</u> <u>26</u> 321

Taste sensitivity and endemic goitre in Israel.

Brand, N. (1964)

<u>Ann. hum. Genet</u> <u>27</u> 233

Taste response and poliomyelitis.

Bransby, E.R., Burn, J.C., Magee, H.E. & Mackneckie, D.M. (1946)

<u>Br. med. J.</u> <u>2</u> 767

Effect of certain social conditions on the health of schoolchildren.

Brewer, E & Haggerty, R.J. (1958)

<u>New Engl. J. Med.</u> <u>259</u> 1038

Toxic hazards rat poison III Thallium, strychnine and ANTU.

Briggs, J.M. & Lillie, R.J. (1946)

Proc. Soc. exp. Biol. Med. 61 430

Perosis caused by feeding high levels of thiouracil

British Standards Institution (1967)

B.S. No: 950 Part I

Specification for artificial daylight for the assessment of colour. Part I. Illuminant for colour matching and colour appraisal.

Broman, B., Dahlberg, G. & Lichtenstein, A. (1942)

Acta pediat. 30 1

Height and weight during growth.

Brothwell, D.R. & Harvey, R.G. (1965)

Eugen. Rev. 57 167

Facial variation

Brothwell, D.R. & Molleson, T. (1965)

Eugen. Rev. 57 131

The frequency of mid-digital hair in Britain.

Brouwer, JN., Van Der Weil, H, Franckea & Henning, GJ. (1968)

Nature, 270 373

Miraculin, the sweetness inducing protein from the miracle fruit.

Brown, E.V.L. (1938)

Archs ophth. N.Y. 19 719

Net average yearly changes in refraction of atropinized eyes from birth to beyond middle life.

Brown, J.L. (1962)

J. genet. Psychol. 100 167

Differential hand usage in 3-year-old children.

Brown, K.S., Maclean, C.M. & Robinette, R.R. (1968)

Hum. Biol. 40 456

The distribution of the sensitivity to chemical odors in man.

Brown, K.S. & Robinette, R.R. (1967)

Nature 215 406

No simple pattern of inheritance in ability to smell solutions of cyanide.

Brues, A.M. (1946a)

Am. J. phys. Anthrop. NS 4 463

Regional differences in the physical characteristics of an American population.

Brues, A.M. (1946b)

Am. J. phys. Anthrop NS 4 1

Genetic analysis of human eye colour.

Brues, A.M. (1950)

Am. J. hum. Genet. 2 215

Linkage of body build with sex, eye colour and freckling

Bryden, M.P. (1963)

J. exp. Psychol. 65 103

Ear preference in auditory perception.

Burke, W.E., Tuttle, W.W., Thompson, C.W., Janney, C.D., & Weber R.J. (1953)

J.appl. Physiol. 5 628

The relation of grip strength and grip strength endurance to age.

Burks, B.S., (1937)

Yb. Carnegie Instn. Wash 33 312

Studies of available data in connection with research projects in the field of human heredity.

Burt, C. (1945)

Man *182* 103

The relation between eye colour and defective colour vision.

Burt, C. (1959)

Br. J. statist Psychol. *12* 16

Class differences in general intelligence.

Burt, C. (1961)

Br. J. statist Psychol. *14* 3

Intelligence and social mobility.

Byerrum, R.V. (1946).

Proc. Soc. exp. Biol. Med. *62* 328

Influence of dietary iodine on susceptibility of rats to alpha-naphthyl-thiourea poisoning.

Calchi-Novati, C., Ceppelini, R., Biancho, I, Silvestroni, E. and Harris, H. (1953-4)

Ann. Eugen. *18* 335

B-aminoisobutyric acid excretion in urine. A family study in an Italian population.

Cannon, F.E. (1941)

J. Hered. *32* 413

The inheritance of ear pits in six generations of a family.

Carroll, K.K., & Noble, R.L. (1949)

J. Pharmac. exp. Ther *97* 478

Resistance to toxic thiourea in rats treated with antithyroid compounds.

Carter, C.O. (1962)

Human Heredity.

Penguin Press.

Cartwright, R.A. & Sunderland, E. (1967)

Acta genet. Statist. med. 17 211

PTC tasting ability in populations in the north of England, with a note on endemic goitre.

Cattell, R.B. (1946)

J. Personality 14 239

The Riddle of Perseveration: II.

Cattell, R.B., Young, H.B. & Hundleby, J.D. (1964)

Am. J. hum. Genet. 16 397

Blood groups and personality traits.

Cawley, R.H., McKeown, T. & Record, R.G. (1954)

Am. J. hum. Genet. 6 484

Parental stature and birth weight.

Cederlöf, R., Friberg, L., Jonsson, E. & Jaij, L. (1961)

Acta genet. Statist. med. 11 388

Studies on similarity diagnosis in twins with the aid of mailed questionnaires.

Černáček, J. (1964)

J. neurol. Sci. 1 152

Handedness as a quantative estimation.

Chamberlain, H.B. (1928)

J. Hered. 19 557

Inheritance of left-handedness.

Chang, K.S.E, Lee, M.M.C, Low, W.D. & Kuan, E. (1963)

Am. J. phys. Anthrop. 21 497

Height and weight of Southern Chinese children.

Chattopadhyay, P.K. (1966a)

Acta Genet. med. Gemell. 15 321

A note on the frequency of hairy ear rims, tragus hair and hairs on the ear lobe in some southern Indian populations residing at Delhi.

Chattopadhyay, P.K. (1966b)

J. Genet. 59 329

Inheritance of hairy pinna of the ear.

Chung, C.S., Witkop, C.J. & Henry, J.C. (1964)

Am. J. hum. Genet. 16 231

A genetic study of dental caries with special reference to PTC taste sensitivity.

Clark, M.M. (1957)

Left-handedness - laterality characteristics and their educational implications

University of London Press.

Clark, P.J. (1956)

Am. J. hum. Genet. 8 49

The heritability of certain anthropometric characteristics as ascertained for measurement of twins.

Clarke, C.A., Price Evans, D.A., McConnell, N.B. & Sheppard, A.M. (1959).

Br. med. J. I. 603

Secretions of blood group antigens and peptic ulcers.

Clements, E.M.B. (1954).

Archs Dis. Childh. 29 147

The ages of children when growth in stature ceases.

Clements, E.M.B, & Pickett, K.G. (1954a)

Br. J. pfev. soc. Med. 8 99

Body-weight of men related to stature, age and social status.

Clements, E.M.B. & Pickett, K.G. (1954b)

Br. J. prev. soc. Med. 8 108

Chest girth of men related to stature, age and social status.

Clements, E.M.B. & Pickett, K.G. (1957)

Br. J. prev. soc. Med 11 51

Stature and weight of men from England and Wales in 1941.

Clements, F.W. & Wishart, J.W. (1956)

Metabolism 5 623

A thyroid blocking agent in the etiology of endemic goitre.

Cliquet, R.L. (1968)

Hum. Biol. 40 17

Social mobility and the anthropological structure of populations.

Cohen, J. & Ogden, D.P. (1949a)

Psychol. Bull. 46 490

Taste blindness to phenylthiocarbamide and related compounds.

Cohen, J. & Ogden, D.P. (1949b)

Science N.Y. 110 532

Taste blindness to phenylthiocarbamide as a function of saliva.

Cole, B.L. (1963)

Br. J. physiol. Optics 20 113

Misuse of the Ishihara test for colour blindness

Collins, E.H. (1961)

Hum. Biol. 33 293

The concept of relative limb dominance.

Conway, J. (1958)

Br. J. statist Psychol. 11 171

The inheritance of intelligence and its social implications.

Covarrubias, E., Barzelatto, J., Stevenson, C., Bobadilla, E., and
Parde, A. & Beckers, C. (1965)
Nature 205 1036
Taste sensitivity to PTC and endemic goitre among
Pewenche Indians.

Cowie, V. (1956)
Ann. hum. Genet. 21 170
Hair colour in the infantile Fanconi syndrome.

Cowie, V., & Penrose, L.S. (1950-51)
Ann. Eugen. 15 297
Dilution of hair colour in phenylketonurics.

Craig, J.O. (1963)
Hum. Biol. 35 524
The heights of Glasgow boys : secular and social
influences.

Cromwell, H. & Rife, D.C. (1942)
Hum. Biol. 14 516
Dermatoglyphics in relation to functional handedness.

Cummins, H. (1940)
Am. J. phys. Anthrop. 26 151
Finger prints correlated with handedness.

Cummins, H., Leche, S. & McClure, K. (1931)
Am. J. Anat. 48 199
Bimanual variations in palmar dermatoglyphics.

Daft, F.S., Kornberg, A., Ashburn, L.C. & Sebrell, W.H. (1946)
Proc. soc. exp. Biol. Med 61 154
Granulocytopenia in rats given thiourea and thyroxin.

Damon, A. & Nuttall, R.L. (1965)
Hum. Biol. 37 23
Ponderal index of fathers and sex ratio of children.

Danforth, C.H. (1921)

Am. J. phys. Anthrop. 4 189

Distribution of hair on the digits of man

Dann, T.C. & Roberts, P.F. (1961)

Br. J. prev. soc. Med. 23 65

Physique and family environment in girls attending a Welsh college.

Das, B.M. (1967)

Acta genet. Statist. med. 17 154

A note on the variation of ear lobe attachment.

Das, S.R. (1956)

Ann. hum. Genet. 20 334

A contribution to the genetics of PTC taste character based on the study of 845 sib pairs.

Das, S.R. (1958)

Ann. hum. Genet. 22 200

Inheritance of PTC taste character in man.

Das, S.R., Mukherjee, D.P. & Bhattacharajee, P.N. (1963)

Acta genet Statist. Med. 13 369

PTC taste threshold distributions in the Bado Gadhaba and the Barang Paroja of Koraput District in Orissa.

Das, S.R., Mukherjee, D.P. (1964).

Acta genet Statist. med. 14 168

Phenylthiocarbamide taste sensitivity survey among the Pareng Gadaba, the Oblaro Gadaba and the Konda Paroja of Koraput District, Orissa.

Davenport, C.B. (1917)

Genetics 2 313

Inheritance of stature.

Davenport, C.B. (1927)

Biblphia genet. 3 443

Heredity of human eye colour.

Davenport, C.B. (1932)

Am. J. phys. Anthrop. 17 167

Growth of the human foot.

Dawson, G.W.P. (1964)

Ann. hum. Genet. 28 49

Blood group frequencies in some occupational groups in county Dublin.

Dawson, W., West, G.B. & Kalmus, H. (1967)

Ann. hum. Genet. 30 273

Taste polymorphism to anetholtrithione and phenylthiocarbamate.

Dencker, S.J., Hauge, M. & Kaig, L. (1959)

Acta genet. Statist. med. 9 236

An investigation of the PTC taste character in monochorionic twin pairs.

Dencker, S.J., Hauge, M., Kaig, L. & Nielsen, A. (1961)

Acta genet. Statist. med. 265

The use of anthropological traits and blood groups in the determination of the zygosity of twins.

Dieke, S.H., Allen, C.S. & Richter, C.P. (1947)

J. Pharmac. exp. Ther. 90 260

Acute toxicity of thiourea and related compounds to wild and domestic Norway rats.

Dieke, S.H. & Richter C.P. (1946)

Proc. Soc. exp. Biol. Med. 62 22

Age and species variation in the acute toxicity of alpha naphthyl thiourea.

Douglas, J.W.B., Ross, J.M. & Simpson, H.R. (1965)

Hum. Biol. 37 178

The relation between height and measured ability in schoolchildren of the same SC, family size and state of sexual development

Dronamraju, K.R. (1963)

Ann. hum. Genet. 27 113

Reading of Ishihara 1959 plates 14 and 15: a new X-linked colour vision anomaly.

Dronamraju, K.R. (1966)

Acta genet. Statist. med. 16 258

Ear lobe attachment in the Buffalo region.

Du Bois, K.P., Holm, C.W. & Doyle, W.L. (1946)

Proc. Soc. exp. Biol. Med 61 102

Biochemical changes following poisoning of rats by alpha-naphthyl-thiourea.

Duggins, O.H. & Trotter, M. (1951)

Ann. N.Y. Acad. Sci. 53 569

Changes in morphology of hair during childhood.

Dutta, P.C. (1963)

Acta genet. Statist. med. 13 290

A note on the ear lobe.

Dutta, P.C. (1965a).

Acta genet. Statist. med. 15 70

The inheritance of the radially curved little finger.

Dutta, P.C. (1965b).

J. R. anthrop. Inst. 95 115

On the variability of middle phalangeal hair among Indian populations.

Dutta, P.C. (1966a)

Acta genet. Statist. med. 16 327

A review of the inherited defective colour vision variability and selection relaxation among the Indians.

Dutta, P.C. (1966b)

Acta genet. Statist. med. 16 95

Biological differences in middle phalangeal pilosity of the Indians.

Dutta, P.C. & Ganguly, P. (1965)

Acta genet. Statist med. 15 77

Further observations on ear lobe attachment.

Dvorine, I (1965)

Am. J. Optom. 42 486

Heredity and colour blindness

Eichorn, D.H.& McKee, J.P. (1953)

Child Dev. 24 235

Oral temperature and subcutaneous fat during adolescence.

Ellis, H. (1904)

A Study of British Genetics

Hurst & Blackett, Ltd.

Ellis, R.W.B. (1945)

Archs Dis. Childh. 20 97

Growth and health of Belgian schoolchildren during and after the German occupation 1940-44.

Elsberg, C.A., Brewer, E.D. & Levy, I. (1935)

Bull. neurol. Inst. N.Y. 4 31

The sense of smell III concerning conditions which may temporarily alter normal olfactory acuity.

Emler, J.T. (1947)

Am. J. publ. Hlth. 37 721.

Baltimore communal rat control program.

Evans, G.J. & Prior, I.A.M. (1969)

Br. J. prev. soc. Med. 23 56

Indices of obesity derived from height and weight in two Polynesian populations.

Falconer, D.S. (1947)

Ann. Eugen. 13 211

Sensory thresholds for PTC.

Falconer, D.S. (1961)

Introduction to Quantative Genetics.

Oliver & Boyd.

Falek, A. (1959)

Am. J. hum. Genet. 11 52

Handedness - a family study.

Ferrer, M.I., Spain, D.M. & Cathcart, R.T. (1945)

J. Am. med. Ass. 127 646

Fatal agranulocytosis resulting from thiouracil.

Fischer, R & Griffin, F. (1959)

Experimentia 15 447

On factors involved in the mechanism of 'taste-blindness'

Fischer, R. & Griffin, F. (1961)

Experimentia 17 36

Quinine dimorphism among 'non-tasters' of 6-n-propylthiouracil.

Fischer, R. & Griffin, F. (1963)

Nature 200 343

Quinine dimorphism: a cardinal determinant of taste sensitivity.

Fischer, R. & Griffin, F.

Arzneimittel-Forsch. 14 673

Pharmacogenetic aspects of gustation.

Fischer, R., Griffin, F., England, S. & Garn, S.M. (1961)

Nature 191 1328

Taste thresholds and food dislikes.

Fischer, R., Griffin, F. & Kaplan, A.R. (1963a)

Genetics Today (Proc. XIth International Congress of Genetics) Vol. 1. 15:67. Pub. Pergamon Press

Pharmacogenic aspects of taste.

Fischer, R., Griffin, F. & Kaplan, A.R. (1963b)

Med. Exp. 9 151

Taste thresholds, cigarette smoking and food dislikes.

Fish, G.H. (1955)

Br. J. prev. soc. Med. 9 48

Incidence of minor maladies and their relationship to intelligence in schoolchildren.

Fisher, R.A. (1958)

The Genetical Theory of Natural Selection.

Dover Publications, Inc., N.Y.

Fisher, R.A. & Roberts, J.A. (1943)

Nature 151 640

A sex difference in blood group frequency.

Flesch, P. & Rothman, S. (1945)

J. invest. Derm. 6 257

Isolation of an iron pigment from human red hair.

Fleure, H.J. & Davies, E. (1958)

J. R. anthrop. Inst. 88 45

Physical characters among Welshmen.

Fleure, H.J., James, T.C. (1916)

J.R. anthrop. Inst. 46 35

Geographical distribution of anthropological types in Wales.

Flory, L.L. (1966)

Vox Sang. 11 137

Differences in the H antigen on human buccal cells from secretor and non-secretor individuals.

Ford, E.B. (1964)

Ecological Genetics

Methuen & Co., Ltd. London.

Fox, A.L. (1932)

Proc. natn. Acad. Sci. U.S.A. 18 115

The relationship between chemical constitution and taste.

François, J. (1961).

Heredity in Ophthalmology.

Mosky, St. Louis.

Fraser, G.R. (1961)

Lancet 1 964

Cretinism and taste sensitivity to phenylthiocarbamide.

Fraser, G.R. (1963)

Ann. hum. Genet. 26 335

A genetical study of goitre.

Freire-Maia, A. (1960).

Ann. hum. Genet 24 333

Smoking and PTC sensitivity

Freire-Maia, A. & Almeida, J (1966)

Hum. Biol. 38 175

Hand clasping and arm folding among African negroes.

Freire-Maia, A. & Quelce-Salgado, A. (1960a)

Am. J. phys. Anthrop. 18 235

Genetic analysis in Russian immigrants.

Freire-Maia, A. & Quelce-Salgado, A. (1960b)

Ann. hum. Genet 24 97

Taste sensitivity to PTC in samples from three Brazilian populations.

Freire-Maia, N., Quelce-Salgado, A. & Freire-Maia, A (1958)

Hum. Biol. 30 281

Hand clasping in different ethnic groups.

Friend, G.E. & Bransby, E.R. (1947)

Lancet 2 677

Physique and growth of schoolboys

Frisch, R.E. & Revelle, R. (1969a)

Hum. Biol. 41 536

The height and weight of adolescent boys and girls at the time of peak velocity of growth.

Frisch, R. & Revelle, R. (1969b)

Hum. Biol. 41 185

Variations in body weights and the age of the adolescent growth spurt among Latin American and Asian populations in relation to calory supplies.

Furusho, T. (1968)

Hum. Biol. 40 437

On the manifestation of genotypes responsible for stature.

Gaines, R.E. & Elston, R.C.

Am. J. hum. Genet. 21 457

On the probability that a twin pair is monozygotic.

Ganguly, P. & Pal, A. (1963)

East. Anthrop. 16 122

Distribution of middle phalangeal hair among Chowra and Tenessa Islanders.

Gardner, B.B. & MacAdam, D.L. (1934)

Am. J. phys. Anthrop. 19 187

Colormetric analysis of hair colour.

Gargill, S.L. & Lesses, M.F. (1945)

J. Am. med. Ass. 127 890

Toxic reactions to thiouracil.

Garn, S.M. (1950)

Am. J. phys. Antrop. 9 325

The use of mid-digital hair in population studies.

Garn, S.M. & Haskell, J.A. (1959)

Science 129 1615

Fat changes during adolescence.

Garn, S.M. & Haskell, J.A. (1960)

Am. J. Dis. Child. 99 746

Fat thickness and developmental status in childhood and adolescence.

Garn, S.M. & Saalberg, J.H. (1953)

Hum. Biol. 25 144

Sex and age differences in the composition of the adult leg.

Garn, S.M. & Young, R.W. (1956)

Am. J. phys. Anthrop. 14 497

Concurrent fat loss and gain.

Garrison, R.J., Anderson, V.E. & Reed, SC. (1968)

Eugen. Q. 15 113

Assortative Marriages.

Gartler, S.M., Dobzhansky, T. & Berry, H.K. (1955)

Am. J. hum. Genet. 7 108

Chromatographic studies in urinary excretion patterns in MZ and DZ twins.

Gartler, S.M. & Sparkes, R.S. (1963)

Lancet 2 411

The Lyon Beutler hypothesis and isochrome X patients with the Turner syndrome

Gates, R.R. (1954)

J. Génet. hum. 3 95

Nouvelles observations concernant les oreilles en particulier les lobes.

Gates, R.R., Chakravartti, M.R. & Mukherjee, D.R. (1962)

Am. J. hum. Genet. 14 363

Final pedigrees of Y chromosome inheritance.

George, R. (1930)

Anat. Rec. 46 199

Human finger types.

Giles, E., Hansen, A.T., McCullough, J.M., Metzger, D.G. & Wolpoft, M.H. (1968)

Am. J. phys. Anthrop 28 203

Hydrogen cyanide and phenylthiocarbamide sensitivity, Mid-phalangeal hair and color blindness in Yucatan, Mexico.

Glanville, E.V. & Kaplan, A.R. (1965a)

Nature 205 930

Taste perception and the menstrual cycle.

Glanville, E.V. & Kaplan, A.R. (1965b)

Am. J. Obstet. Gynec. 92 189

The menstrual cycle and sensitivity of taste perception.

Glanville, E.V. & Kaplan, A.R. (1965c)

Nature 205 851

Food preference and sensitivity for bitter compounds.

Glanville, E.V., Kaplan, A.R. & Fischer, R. (1964).

J. Geront. 19 474

Age, sex and taste sensitivity.

Glass, B. (1956)

Am. J. phys. Anthrop. 14 541

On the evidence of random genetic drift in human populations.

Glass, B. & Kistler, J.C. (1953)

Acta genet. Statist. med. 4 192

Distal hyperextensibility of the thumb.

Glass, B., Sacks, M.S., Jahn, E.F. & Hess, C. (1952)

Am. Nat. 86 145

Genetic drift in a religious isolate.

Glass, L.C. & Magee, E. (1935)

J. Hered. 26 490

The inheritance of crooked little finger.

Goedde, H.W. & Ohligmacher, H. (1965)

Humangenetik 1 423

The polymorphism of bitter tasting: comparative investigations on thiourea derivatives and anetholtrithione.

Goedde, H.W. & Ohligmacher, H. (1966)

Acta genet. Statist. med. 16 350

Taste thresholds of thiourea derivatives and anetholtrithione in twins.

Goldschmidt, E. (1966)

Acta Ophthal. 44 751

Myopia and height.

Goldthorpe, J.H. & Lockwood, D. (1963)

<u>Sociol. Rev. 11</u> 133

Affluence and the British class structure.

Goldthorpe, J.H., Lockwood, D., Bechhofer, F. & Platt, J. (1967)

<u>Sociology</u> <u>1</u> 11

The affluent worker and thesis of embourgeoisment.

Goodglass, H. & Quadfase, F. (1954)

<u>Brain</u> <u>77</u> 521

Language laterality in left handed aphasics.

Gorden, H. & Riser, G.M. (1966)

<u>S. Afr. med. J.</u> <u>40</u> 1147

Age and genetical variability

Gorman, W. (1964)

<u>Eye Ear Nose Throat mon</u> <u>43</u> 65

General discussion of tasting.

Gorrell, G.J. (1967)

<u>Ann. hum. Genet.</u> <u>31</u> 39

A study of defective colour vision with the Ishihara test plates.

Grant, G. & Hitchens, R.A.N. (1953)

<u>Br. J. prev. soc. Med.</u> <u>7</u> 60

Some observations on the heights and weights of undergraduates.

Grant, M.W. (1964)

<u>Br. J. prev. soc. Med.</u> <u>18</u> 35

Rate of growth in relation to birth rank and family size.

Green, R., Farran, H. & Glascock, R.F. (1958)

<u>J. Endocr.</u> <u>17</u> 272

Goitrogens in milk.

Greenberg, B.G. & Bryan, A.H. (1951)

<u>Hum. Biol.</u> <u>23</u> 160

Methodology in the stddy of physical measurements of schoolchildren.

Greer, M.A. (1957)

<u>Am. J. clin. Nutr.</u> <u>5</u> 440

Goitrogenic substances in food.

Greer, M.A. (1962)

<u>Recent Prog. Horm. Res.</u> <u>18</u> 187

Thyroid hormones - the natural occurrence of goitrogen agents.

Greer, M.A. & Astwood, E.B. (1948)

<u>Endocrinology</u> <u>43</u> 105

Antithyroid effect of certain foods in man as determined with radioactive iodine.

Greisbach, W.E., Kennedy, T.H. & Purves, H.D. (1944)

<u>Nature</u> <u>154</u> 610

Protective action of Potassium Iodide on thiourea poisoning of rats.

Greulich, W.W. (1951)

<u>Am. J. phys. Anthrop.</u> <u>9</u> NS 55

The growth and developmental status of Guamanian schoolchildren in 1947.

Grieve, J. & Morant, G.M. (1947)

<u>Ann. Eugen. 13</u> 161

Records of eye colours for British populations and a description of a new eye colour scale.

Griffin, F., & Fischer, R. (1960)

Nature 187 417

Differential reaction of saliva from tasters and non-tasters of 6.n.propylthiouracil.

Guttman, R., Rosenzweig, K.A. & Guttman, L. (1965)

Acta genet. Statist. med. 15 358

The retest reliability of the observation of certain traits.

Hall, A.R. & Blakeslee, A.F. (1945)

Proc. natn. Acad. Sci. U.S.A. 31 390

Effect of smoking on taste thresholds for phenylthiocarbamide.

Hammond, W.H. (1953)

Br. J. prev. soc. Med. 7 231

Physique and development of boys and girls from different types of school.

Hammond, W.H. (1955a).

Br. J. prev. soc. Med. 9 201

Measurement and interpretation of subcutaneous fat, with norms for children and young adult males.

Hammond, W.H. (1955b)

Br. J. prev. soc. Med. 9 152

Body measurements of pre-school children.

Hammond, W.H. (1957)

Br. J. prev. soc. Med. 11 131

Some aspects of growth with norms from birth to 18 years.

Hanna, B.L. (1953)

Am. J. hum. Genet. 5 293

On the relative importance of genetic and environmental factors in determination of human hair pigment concentration.

Hanna, B.L. (1956)

Am. J. phys. Anthrop 14 NS 153

Colorimetric estimation of the pigment concentration in hair of various colour grades.

Hanna, BL. (1961)

Am. J. phys. Anthrop 19 351

Comparative spectrophotometric absorption of the pigments from human non-red hair.

Hardy, L.H. (1945)

Archs Ophthal. N.Y. 34 278

Standard illuminants in relation to color testing procedure.

Hardy, L.H., Rand, G. & Rittler, M.C. (1954a)

Archs Ophthal. N.Y. 51 216

The H.R.R. polychromatic plates.

Hardy, L.H., Rand, G. & Rittler, M.C. (1954b)

Archs Ophthal. N.Y. 52 353

The H.R.R. polychromatic plates.

Hardy, L.H., Rand, G. & Rittler, M.C. (1957)

AO H.R.R. Pseudo Isochromatic Plates

American Optical Co.

Hare, E.E. (1955)

Br. J. prev. soc. Med. 9 191

Mental illness and social class in Bristol.

Haro, F.G. (1963)

Genetics Today. Proc. XIth Congress of Genetics. ed. S.O. Geerts pub. Pergamon Press. Vol. I 15. 69

Relation between blood groups of the ABO system and taste sensibility to phenylthiourea (PTC).

Harris, A.J. (1957)

J. Psychol. 44 283

Lateral dominance, directional confusion and reading disability.

Harris, A.J. (1958)

Harris Tests of Lateral Dominance

Psychological Corporation, 304 East 45th St. N.Y.

Harris, H. (1953-4)

Ann. Eugen. 18 43

Family studies on the urinary excretion of beta - aminoisobutyric acid.

Harris, H. (1966)

Human Biochemical Genetics

Cambridge University Press.

Harris, H. & Kalmus, H. (1949-50)

Ann. Eugen 15 24, 32

Measurement of taste sensitivity to PTC.

Harris H., & Kalmus, H. (1950-51)

Ann. Eugen. 16 226

The distribution of taste thresholds of phenylthiourea in 304 sib pairs.

Harris, W. (1952)

Br. med. J. I 831

The 5th and 7th nerves in relation to the nervous mechanism of taste sensation.

Hartmann, G. (1939)

Ann. Eugen. 9 123

Application of individual taste differences towards PTC in genetic investigation.

Hatt, D. & Parsons, P.A. (1965)

Acta genet. Statist. med. 15 309

Association between surnames and blood groups in the Australian population.

Hauge, M., Helweg-Larsen, H.F.(1953-54)

Ann. Eugen. 18 175

Studies in linkage in man. Red hair versus blood groups, PTC and eye colour.

Heady, JA., Morris, J.N., Kagan, A & Raffle, P.A. (1961).

Br. J. prev. soc. Med. 15 143

Coronary heart disease in London busmen - a progress report with particular reference to physique.

Heath, C.W. (1954).

Hum. Biol. 26 337

Physique, temperament and the sex ratio.

Helweg-Larsen, H. (1947)

Ann. Eugen. 14 1

Situs inversus in one monozygotic twin.

Henkib, R.I. & Bradley, D.F. (1967)

Proc. natn. Acad. Sci. U.S.A. 62 30

Regulation of taste acuity by thiols and metal ions.

Henkin, R.I., Gill, J.R. & Bartter, F.C. (1963)

J. clin. Invest. 42 727

Studies on taste thresholds in normal man and in patients with adrenal cortical insufficiency.

Henkin, R.I. & Powell, G.F. (1962)

Science 138 1107

Increased taste sensitivity in cystic fibrosis.

Hertzberg, H.T.E., Churchill, E., Dupertuis, C.W., White, R.M. and Daman, A. (1963)

Anthropometric Survey of Turkey, Greece and Italy. pub. for Advisory Group for Aeronautical Research and Development, NATO. Pergamon Press.

van Herwerden MA, & Baele-Nyland, P. (1930)

Proc. natn. Acad. Sci. Amst. 33 659

Investigations of blood groups in Holland.

Hewitt, D. & Stewart, A. (1952)

Hum. Biol. 24 308

The Oxford Child Health Survey: a study of the influence of social and genetic factors on infant weights.

Hewitt, D., Westropp, C.K. & Acheson, R.M. (1955)

Br. J. prev. soc. Med. 9 179

The Oxford Child Health Survey: the effect of childish ailments on skeletal development.

Hill, J.B. & Hill, H.D. (1955)

Genetics and Human Heredity.

McGraw Hill.

Hill, L.M. (1958)

Am. J. phys. Anthrop. 16 349

Changes in the proportions of the female foot during growth.

Hiorns, R.W. & Harrison, G.A. (1970).

<u>Hum. Biol</u>. <u>42</u> 51

Sampling for the detection of natural selection by age group genetic differences.

Hirsch, M.J. (1952)

<u>Am. J. Optom</u>. <u>29</u> 445

The changes in refraction between the ages of 5 and 14 - theoretical and practical considerations.

Hirsch, M.J. (1964)

<u>Am. J. Optom</u>. <u>41</u> 395

Refraction of children.

Hoch, M.O. (1949)

<u>J. Hered</u>. <u>40</u> 132

Clover leaf tongue.

Holt, S.B. (1953-54).

<u>Ann. Eugen</u>. <u>18</u> 211

Genetics of dermal ridges: bilateral asymmetry in finger ridge counts.

Hooton, E.A. (1940)

<u>Am. J. phys. Anthrop</u>. <u>26</u> 229

Stature, head form and pigmentation of the adult Irish male.

Hooton, E.A. & Dupertuis, C.W. (1955)

<u>Papers of the Peabody Museum</u> <u>30</u> Nos. 1-2.

The physical anthropology of Ireland.

Hoover, E.F. (1956)

<u>J. agric. Fd. Chem</u> <u>4</u> 345

Taste perception: reliability of phenylthiocarbamide-sodium benzoate method of determining taste classification.

Hopkins, J.W. (1947)

Hum. Biol. 19 68

Height and weight of Ottawa elementary school children of two socio-economic strata.

Howe, P.E. & Schiller, M. (1952)

J. appl. Physiol. 5 51.

Growth responses of the school child to changes in diet and environmental factors.

Hoyne, I.E. (1955)

J. Hered. 46 167

Genetics, physiology and PTC.

Huber, N.M. (1969)

Am. J. phys. Anthrop. 31 171

Ponderal index and height.

Hughes, D.R. (1963)

Man 63 137

Polygenic or multifactorial variables in man: redressing the balance.

Humphrey, M.E. (1951)

Br. J. educ. Psychol. 21 214

Consistency of hand usage.

Hunt, E.E. & Barton, W.H. (1959)

Am. J. phys. Anthrop 17NS 27

The inconsistency of physique in adolescent boys and other limitations of somatotyping.

Hsu, T.C. (1948)

J. Hered. 39 186

Tongue upfolding.

Hutt, F.B. (1947)

J. Hered. 38 377

Odd familial PTC reaction.

Huxley, J., Mayr, E., Osmond, H. & Hoffer, A. (1964)

Nature 204 220

Schizophrenia as a genetic morphism.

Illesley, R. (1955)

Br. med. J. 1955 2 1520

Social class selection and class differences in relation to stillbirths and infant deaths.

Ishihara, S. (1964)

Tests for Color Blindness

pub. Kanehara Co. Ltd. Toyko.

(London H.K. Lewis & Co., Ltd.)

Jarvik, L.F., Falek, A., Schmidt, R. & Platt, M. (1969)

Human Hered. 19 668

The mixed leukocyte reaction as a possible test of zygosity in twins.

Jenkins, T. (1965)

Hum. Biol. 37 371

Ability to taste PTC among Kalahari bushmen and southern Bantu.

Jenss, R.M. (1940)

Hum. Biol. 12 532

Gain in weight and its association with ancestry and economic status.

Jevons, N.A. (1957)

Med. Offr. 117 53

Ocular defects and intelligence.

Johnson, W. & Davies, D. (1937)

J. educ. Psychol. 28 346

Dextrality quotients of 7 year olds in terms of hand usage.

Johnston, F.E., Herzog, K.P., Malina, R.M. (1966)

Am. J. phys. Anthrop. 24 253

PTC taste sensitivity and its relationship to growth variation.

Joint Clothing Council, Ltd. (1957)

Women's Measurements and Sizes.

H.M.S.O.

Jones, H.E. (1947)

Hum. Biol. 19 12

Sex differences in physical ability.

Kaelber, C.T. & Pughl, T.F. (1969)

New.Engl. J. Med. 280 1030

Influence of intrauterine relations on the intelligence of twins.

Kahn, J. & Stock, R.P. (1944)

J. Am. med. Ass. 126 358

Fatal agranulcytosis resulting from thiouracil.

Kalmus, H. (1958)

Ann. hum. Genet. 22 222

PTC tasting: improvements in the classification of the taster genotypes.

Kalmus, H. (1965)

Diagnosis and Genetics of Defective Colour Vision

Pergamon Press, Oxford.

Kalmus, H. & Maynard Smith, S. (1965)

Ann. hum. Genet. 29 127

The antimode and lines of optimum separation in a genetically determined bimodal distribution, with particular reference to PTC sensitivity.

Kalmus, H. & Trotter, W.R. (1962)

Ann. hum. Genet. 26 145

Direct assessment of the effect of age on PTC sensitivity.

Kalmus, H., De Garay, A.C., Rodarke, U. & Cobo, L. (1964).

Hum. Biol. 36 134

The frequency of PTC tasting, hard ear wax, colour blindness and other genetical characters in urban and rural Mexican populations.

Kaplan, A.R. (1963)

J. Hered. 54 35

The inheritance of relative digit size in the human foot.

Kaplan, A.R. (1964)

Acta Genet. med. Gemell. 13 295

Genetics of relative toe length.

Kaplan, A.R., Fischer, R., Glanville, E.V., Powell, W., Kamionkowski, M. & Fleshler, B. (1964a)

Gastroenterology 47 604

Differential taste sensitivities in duodenal and gastric ulcer patients.

Kaplan, A.R.., Glanville, E.V. & Fischer, R. (1964b)

Nature 202 1366

Taste thresholds for bitterness and cigarette smoking.

Kaplan, A.R., Powell, W., Fischer, R. & Masters, R. (1963)

Genetics Today (Proc. XIth International Congress of Genetics) Vol. 3 15: 68

Re-examination of genetic aspects of taste thresholds for the thioureas.

Karn, M.N. (1958)

Ann. hum. Genet. 22 385

Considerations arising from weight and some other variables recorded in the Survey of Women's Measurements 1957.

Karpinos, B.D. & Grossman, H.A. (1953)

Hum. Biol. 25 36

Prevalence of left-handedness among selective service registrations.

Keddie, J.A.G. (1956)

Br. J. prev. soc. Med 10 1

Heights and weights of Scottish schoolchildren.

Keddie, J.A.G. (1958).

Med. Offr. 14 Feb 1958 87; 21 Feb 1958 101.

Heights and weights of Scottish schoolchildren of different socio-economic groups.

Kelly (1967-68)

Kelly's Directory of Birmingham (1967-68)

Chapell River Press, Andover. 99th edn.

Kemsley, W.F.F. (1951)

Ann. Eugen. 15 161

Weight and height of a population in 1943.

Kemsley, W.F.F., Billewicz, W.Z. & Thomson, AM. (1969)

Br. J. prev. soc. Med. 16 189

A new weight for height standard based on British anthropometric data.

Kennedy, T.H. (1942)

Nature 150 233

Thioureas as goitrogenic substances.

Khosla, T. & Lowe, C.R. (1967)

Br. J. prev. soc. Med. 21 122

Indices of obesity derived from body weight and height.

Kiil, V. (1948a)

J. Hered. 39 206

Inheritance of frontal hair direction in man.

Kiil, V. (1948b)

J. Hered. 39 281

Frontal hair direction in mentally deficient individuals.

Kirk, R.L. & Stenhouse, N.S. (1953)

Nature 171 698

Ability to smell solutions of KCN.

Kitchin, F.D., Howel-Evans, W., Clarke, C.A., McConnell, K.B. & Sheppard, P.M. (1959)

Br. med. J. I 1069

PTC taste response and thyroid disease.

Kloepfer, H.W. (1946-47)

Ann. Eugen. 13 35

An investigation into 171 possible linkage relationships in man.

Knott, V.B. & Meredith, H.V. (1963)

Hum. Biol. 35 507

Body size of United States schoolboys at ages from 11 years to 15 years.

Kornfeld, W. (1957)

Hum. Biol. 29 62

Typical and atypical changes in the soft tissue distribution during childhood.

Krill, A.E., Bowman, J.E. & Schneiderman, A. (1966)

Ann. hum. Genet. 29 253

An investigation of so-called X-linked errors on the Ishihara plates.

Krogman, W.M. (1967)

Eugen. Rev. 59 165

The role of genetic factors in the human face, jaws and teeth: a review.

Krut, L.H., Perrin, M.J. & Bronte-Stewart, B. (1961)

Br. med. J. I 384

Taste perception in smokers and non-smokers.

Kurihara, K. & Beidler, L.M. (1961)

Nature 222 1176

Mechanism of the action of the taste modifying protein.

Kurihara, K. & Beidler, L.M. (1968)

Science 161 1241

Taste modifying protein from miracle fruit.

Lai, L.Y.C. & Walsh, R.J. (1965)

Hum. Biol. 37 312.

The patterns of hand clasping in different ethnic groups.

Lai, LYC, & Walsh, R.J. (1966)

<u>Acta genet. Statist. med.</u> <u>16</u> 250

Observations on ear lobe type.

Lakowski, R. (1969a)

<u>Br. J. ind. Med. 26 173</u>

Theory and practice of colour vision testing.

A review, Part 1.

Lakowski, R. (1969b)

<u>Br. J. ind. Med. 26 265</u>

Theory and practice of colour vision testing.

A review, Part 2.

Landsdell, H. (1962)

<u>Science</u> <u>135</u> 922

Laterality of verbal intelligence in the brain.

Lasselle, P.A. & Williams, R.J. (1926)

<u>J. Am. chem. Soc.</u> <u>48</u> 536

The identification of creatine.

Laycock, F. & Caylor, J.S. (1964)

<u>Child Dev.</u> <u>35</u> 63

The physique of gifted children and their less

gifted siblings.

Lea, A.J. (1954)

<u>Ann. hum. Genet.</u> <u>19</u> 97

Estimation of the amount of pigment present in

human hair.

Leathem, J.H. (1946)

<u>Proc. Soc. exp. Biol. Med.</u> <u>61</u> 203

Influence of thiourea on organ weights of rats

related to food intake.

Lebow, M.R. & Sawin, P.W. (1941)

J. Hered. 32 127

Inheritance of human facial features.

Lee, C.D. & Penrose, L.S. (1947)

Ann. Eugen. 13 182

A contribution to the genetics of hair colour in man.

Lee, J.A.H. (1957)

Eugen. Rev. 49 19

Regional variations in intellectual ability in Britain.

Le Magnen, J. (1948)

C.r. hebd. Séanc. Acad. Sci. Paris 226 694

Un cas de sensibilité olfactive, se présentant comme un caractere sexuel secondaire féminin.

Levine, P. & Anderson, A.S. (1932)

Science 75 497

Observations on taste blindness.

Lilienfeld, A.M. & Pasamanick, B. (1955)

Am. J. hum. Genet. 7 204

A study of variations in the frequency of twin births by race.

Linder, L. (1948)

Hereditas 35 suppl. 620

The ability to move the ears.

Lipset, S.M. & Bendix, R. (1960)

Social Mobility in Industrial Society

Heinemann.

Liu, T.T. & Hsu, T.C. (1949).

J. Hered. 40 19

Tongue folding and tongue rolling in China.

Lombard, O.M. (1950)

Child Dev. 21 229

Breadth of bone and muscle by age and sex in childhood.

Lu, K.H. (1965)

Biometrics 21 491

Harmonic analysis of the human face.

Luell, E. & Archer, V.E. (1964)

Am. J. phys. Anthrop. 22 107

Hair medulla variation with age in human males.

Lugg, J.H.W. (1957)

Ann. hum. Genet. 21 244

Taste thresholds for phenylthiocarbamide in some population groups. II.

Lugg, J.H.W. (1962)

Nature 194 980

Some extremely high acuities of taste for phenylthiocarbamide.

Lugg, J.H.W. (1966)

Ann. hum. Genet. 29 217

Taste thresholds for PTC of some population groups III.

Lugg, J.H.W. (1968)

Ann. hum. Genet. 32 43

Taste thresholds for PTC of some population groups IV.

Lugg, J.H.W. & Whyte, J.M. (1955)

Ann. hum. Genet. 19 290

Taste thresholds for PTC in some population groups I.

Lutz. F.E. (1908).

Am. Nat. 42 195

The inheritance of the manner of clasping the hands.

Lygonis, C.S. (1969)

Hereditas 61 413

Familial absence of olfaction.

McBurney, D. & Pfaffman, C. (1963)

J. exp. Psychol. 65 523

Gustatory adaptation to saliva and sodium chloride.

MacConaill, M.A. (1942)

Ann. Eugen. 11 173

The classification of hair and eye colour upon developmental and genetic bases.

McDonough, E.S. (1941)

J. Hered. 32. 169

On the inheritance of ear pit.

Mackenzie, I.F. (1944)

Br. med. J. 2 205

Nutrition and scholastic attainment.

Mackenzie, J.B. & Mackenzie, C.G. (1943)

Proc. Soc. exp. Biol. Med. 54 34

Age, pulmonary oedema and thiourea.

McKeown, T. & Record, R.G. (1954)

Am. J. hum. Genet. 6 457

Influence of prenatal environment on correlation between birth weight and parental height.

Malina, R.J., Holman, J.D., & Harper, A.B. (1970)

Soc. Biol. 17 120

Parent size and growth status of offspring.

Malpas, P. & Symonds, E. (1966)

Ann. hum. Genet. 29 409

The direction of the helix in the human umbilical cord.

Manlapas, F.C., Stein, A.A., Pagliara, A.S., Apicelli, A., Porter, I.H. & Patterson, P.R. (1965).

J. Pediat. 66 8

PTC taste sensitivity in cystic fibrosis.

Manning, J.R. (1955)

Shoe and Allied Trades Research Association Research Report No. 143

A Survey of Women's Feet.

Maresh, M.M. (1955)

Am. J. Dis. Child. 89 725

Linear growth of long bones of extremities from infants through adolescence.

Matsunga, E. (1962)

Ann. hum. Genet. 25 273

The dimorphism in human normal cerumen.

Maynard Smith, S. & Penrose, L.S. (1954)

Ann. Eugen. 19 273

Monozygotic and dizygotic twin diagnosis.

Mayo, O. (1969)

Human Hered. 19 415

The relation between secretor ABO interaction and maintenance of the ABO polymorphism.

Maxwell, J. (1953)

Scottish Council for Research in Education

London University Press.

Social implications of the 1947 Scottish mental survey.

Meadows, S.H. (1961)

Br. J. prev. soc. Med. 15 171

Social class migration and chronic bronchitis.

Mellor, C.S. (1967)

Nature 213 939

Finger prints in schizophrenia.

Meredith, H.V. (1941)

Am. J. Dis. Child. 62 909

Stature and weight of children of the United States.

Meredith, H.V. (1944)

Hum. Biol. 16 207

Human foot length from embryo to adult.

Meredith, H.V. (1951)

Am. J. Dis. Child 82 702

Relation between socioeconomic status and body size in boys 7-10 years of age.

Merrell, D.J. (1957)

Hum. Biol. 29 314

Dominance of hand and eye.

Merton, B.B. (1958)

Acta genet. Statist, med. 8 114

Taste sensitivity to PTC.

Milunicova, A., Jandova, A. & Skoda, V. (1969)

Human Hered. 19 398

Phenylthiocarbamide tasting ability and malignant tumours.

Mohr, J. (1951)

Ann. Eugen. 16 282

Taste sensitivity to PTC in Denmark.

Monn, E. (1969)

Human Hered. 19 678

Further data on the genetics of the ABO, MN and PTC systems of the Norwegian Lapps.

Montague, A. (1947)

J. Hered. 38

The missing fore-arm muscle.

Montague, A. (1960)

Handbook of Anthropometry

pub. C.C. Thomas.

Montague, A. (1962)

J. Am. med. Ass. 182 281

The functions of man's distribution of hair.

Montegriffo, V.M.E. (1968)

Ann. hum. Genet. 31 389

Height and weight of a U.K. adult population with a review of anthropometric literature.

Montenegro, L. (1964)

Ann. hum. Genet. 28 185

PTC tasting among Tucano Indians.

Moran, P.A.P. (1965)

Ann. hum. Genet. 28 261.

Class migration and the schizophrenic polymorphism.

Morgan Watkin, I. (1965)

Heredity 20 83

ABO blood groups, human history and language in Herefordshire.

Morris, J.N. (1959a)

Archs intern. Med. 104 903

Occupation and coronary heart disease.

Morris, J.N. (1959b).

Lancet I 303

Health and social class.

Morris, J.N. & Heady, J.A. (1955)

Lancet 1 554

Social and biological factors in infant mortality V. Mortality in relation to father's occupation.

Morris, J.N., Heady, J.A. & Raffle, P.A.B. (1956)

Lancet 2 569

Physique of London busmen - epidemiology of uniforms.

Morris, J.N., Heady, J.A., Raffle, P.A.B., Roberts, C.G. & Parks, J.W. (1953)

Lancet 1 1053

Coronary heart disease and physical activity of work.

Morris, J.N. & Raffle, P.A.B. (1954)

Br. J. ind. Med. 11 260

Coronary heart diseases in transport workers.

Morton, N.E., Kreiger, H. & Mi, M.P. (1966)

Am. J. hum. Genet. 18 153.

Natural selection on polymorphisms in North Eastern Brazil.

Mourant, A.E. (1959)

Cold Spring Harb. Symp. quant. Biol. 24 57

Human blood groups and natural selection.

Mourant, A.E. & Morgan Watkin, I. (1952)

Heredity 6 13

Blood groups, anthropology and language in Wales and the Western Countries.

Mourant, A.E., Kopéc, A.C. & Domaniewsla-Sobczak, K. (1958)

The ABO Blood Groups. Comprehensive Tables amd Maps of World Distribution

Blackwell Scientific Publications, Oxford.

Motulsky, A.G. (1963)

Genetics Today (Proc. XIth International Congress of Genetics) Vol. 3 873 Pub. Pergamon Press.

Pharmocogenetics.

Muhrer, M.E. & Hogan, A.G. (1945)

Proc. Soc. exp. Biol. Med. 60 211

Effect of thiouracil on swine.

Munroe, R.A., Clarke, H.H. & Heath, B.H. (1968)

Am. J. phys. Anthrop. 30 195

A somatotype method for young boys.

Neel, J.V. (1943)

J. Hered. 34 93

Concerning the inheritance of red hair.

Neel, J.V. & Post, R.H. (1963)

Eugen. Q. 10 33

Transitory 'positive' selection for colour blindness.

Newman, H. H. (1928a)

Biol.Bull. mar. biol. Lab., Woods Hole 55 283

Studies of human twins I Methods of diagnosing monozygotic and dizygotic twins.

Newman, H.H. (1928b)

Biol.Bull. mar. biol. Lab., Woods Hole 55 298

Studies of human twins II Asymmetry, reversal, or mirror image in identical twins.

Newman, H.H. (1930)

Am. J. phys. Anthrop. 14 331

Palmar dermatoglypgics in twins.

Newman, H.H. (1934)

Am. J. Anat. 55 277

Dermatoglyphics and the problem of handedness.

Newman, H.H. (1940)

Hum. Biol. 12 21

The question of mirror imagery in one egg twins.

Newman, H.H., Freeman, F.N. & Holzinger, K.J. (1937).

Twins - a Study of Heredity and Environment

Chicago.

Nicholls, E.M. (1968)

Ann. hum. Genet. 32 15

Microspectrophotometry in the study of red hair.

Nicholls, E.M. (1969,

Human Hered. 19 36

The genetics of red hair.

Nichols, R.C. & Bilbro, W.J. (1966)

Acta genet Statist. med. 16 265

The diagnosis of twin zygosity.

Niswander, J.D., Shreffler, D.C. & Neel, J.V. (1963)

Ann. hum. Genet. 27 319

Genetic studies of quantative variation in a component of human saliva.

Oliver, R.M. (1967)

Br. J. ind. Med. 24 181

Physique and serum lipids of young London busmen in relation to ischaemic heart disease.

Oliver, R.M. (1969)

Br. J. ind. Med. 26 289

Constitutional differences between men recruited for driving and non-driving occupations.

Onslow, H. (1920)

Eugen. Rev. 12 212

Fair and dark: is there a predominant type?

Osborne, R.H. & De George, F.V. (1959)

Genetic Basis of Morphological Variation

Cambridge, (Mass.).

Palatnik, M., Benevides, M.J.F.S. & Salzano, F.M. (1969)

Hum. Biol. 41 83

ABH salivary secretion and white/negro gene flow in a Brazilian population.

Palmer, R.D. (1964)

Psychol. Bull. 62 257

Development of differential handedness.

Papp, M., & Makara, G.B. (1965)

Experimentia 21 692

The taste of L and D amino acids.

Parr, L.W. (1934)

J. Hered. 25 187

Taste blindness and race.

Parsons, F.G. (1920)

J.R. anthrop. Inst. 50 159

The colour index of the British Isles.

Partridge, L., Sunderland, E. & Zeki, S.M. (1962)

Man 62 38

Taste blindness to PTC in the Black Mountain area of Carmarthenshire.

Paschkis, K.E., Cantarow, A., Hart, W.M. & Rakoff, A.E. (1944).

Proc. Soc. exp. Biol. Med. 57 37

Inhibitory action of thiouracil, thiocarbamide and other compounds on melanin formation by tyrosinase.

Paschkis, K.E., Cantarow, A. & Tillson, E.K. (1945)

Proc. Soc. exp. Biol. Med. 60 148

Thiouracil & thyroid cytochrome oxidase.

Patterson, P.N. & Lauder, B.A. (1948)

J. Hered. 39 295

The incidence and probable inheritance of smell-blindness to normal butyl-mercaptan.

Pelecanos, M. (1969)

Hum. Biol. 41 275

Some Greek data on handedness, hand clasping and arm folding.

Phelps, U.R. (1952)

Am. J. hum. Genet. 4 72

Relative index finger length as a sex influenced trait in man.

Pickford, R.W. (1963)

Eugen. Rev. 55 97

Natural selection and colour blindness.

Pickford, R.W. (1964)

Br. J. physiol. Optics 21 39

The genetics of colour blindness.

Pickford, R.W. (1969)

J. biosoc. Sci. 1 3

The frequency of colour vision defective students in a school of art and the influence of their defects.

Pickford, R.W. & Lakowski, R. (1960)

Br. J. physiol. Optics 17 131

The Pickford-Nicholson Anomaloscope.

Pipkin, A.C. & Pipkin, S.B. (1943)

J. Hered. 34 240

Ear pits and albinism in a negro family.

Phillips, B.S. (1960)

Br. med. J. 2 1239

Marksmanship and crossed laterality.

Polyak, S. (1957)

The Vertebrate Visual System.

Chicago University Press.

Pons, J. (1960)

Ann. hum. Genet. 24 71

A contribution to the heredity of PTC taste character.

Pons, J. (1961)

Ann. hum. Genet. 25 141

Hand clasping (Spanish data).

Post, R.H. (1962a)

Eugen. Q. 9 131

Population differences in red and green color vision deficiency: a review and a query on selection relaxation.

Post, R.H. (1962B).

Eugen. Q. 9 189

Population differences in vision acuity.

Post, R.H. (1963a)

Eugen. Q. 10 110

'Colour-blindness' distribution in Britain, France and Japan: a review with notes on selection relaxation.

Post, R.H. (1963b)

Eugen. Rev. 10 21

'Colour-blindness' and relaxed selection.

Post, R.H. (1965a)

Eugen. Q. 12 28

Selection against 'colour-blindness' among 'primitive' populations.

Post, R.H. (1965b)

Anthrop. Anz. 29 186

Notes on relaxed selection in man.

Post, R.H. (1969a)

Soc. Biol. 16 179

Deformed nasal septa and relaxed selection II

Post, R.H. (1969b)

Soc. Biol. 16 257

Population differences in tear duct size: implications of relaxed selection.

Post, R.H. (1969c)

Am. J. phys. Anthrop. 30 85

Tear duct size differences of age, sex and race.

Powell, E.F. & Whitney, D.D. (1937)

J. Hered. 28 185

Ear lobe inheritance.

Prader, A., Tanner, J.M. & von Harnack, G.A. (1963)

J. Pediat. 62 646

Catch-up growth following illness or starvation.

Price, B. (1936)

Am. J. hum. Genet. 2 243

Primary biases in twin studies: a review of prenatal and natal difference-producing factors in monozygotic twins.

Price, J. (1967)

J. med. Genet. 4 44

A comprehensive review article on human polymorphism.

Price, J. (1969)

Br. J. Psychiat. 115 435

An anthropometric comparison of phychiatric patients and their siblings.

Price Evans, D.A., Kitchin, F.D. & Riding, J.E. (1962)

Ann. hum. Genet. 26 123

The metabolism of methyl thiouracil and thiopentone in tasters and non-tasters of PTC.

Pullin, E.W. & Sunderland, E. (1963)

Man 63 52

A survey of PTC tasting and colour blindness in Pembrokeshire.

Race, R.R. & Sanger, R. (1958)

Blood Groups in Man.

Blackwell Scientific Publications, 3rd Edn.

Rakshit, H.K. (1965)

East. Anthrop. 18 125

Incidence of phalangeal hair among the tribes of Bastar.

Ray, A.K. (1969)

Soc. Biol. 16 203

Colour blindness, culture and selection.

Record, R.G., McKeown. & Edwards, J.H. (1969a)

Ann. hum. Genet. 33 61

The relation of measured intelligence to birth order and maternal age.

Record, R.G., McKeown, T. & Edwards, J.H. (1969b)

Ann. hum. Genet. 33 71

Relation of intelligence to birth weight and gestation.

Record, R.G., McKeown, T. & Edwards, J.H. (1970)

Ann. hum. Genet. 34 11

An investigation of the difference in measured intelligence between twins and single births.

Reed, R.B. & Stuart, H.C. (1959)

Pediatrics 24 904

Patterns of growth in height and weight from birth to 18 years of age.

Reed, T.E. (1952)

Ann. hum. Genet. 17 115

Red hair as a genetical character.

Registrar General (1961)

Classification of Occupations

H.M.S.O.

Registrar General (1961)

Occupation Tables

H.M.S.O.

Reynolds, E.L. & Grote, P. (1948)

Anat. Rec. 102 45

Sex differences in the distribution of tissue components of the human body from birth to maturity.

Richardson, J.F. & Pincherle, G. (1969)

Br. J. prev. soc. Med. 23 267

Heights and weights of British businessmen.

Riches, J. (1966)

Nature 211 774

Frequency of colour blindness among East Kentish children.

Richter, C.P. (1945)

J. Am. Med. Ass. 29 927

The development and use of alpha-naphthyl-thiourea (ANTU) as a rat poison.

Richter, C.P. & Campbell, K.H. (1941)

Am. J. Physiol. 134 157

Phenylthiocarbamide taste thresholds of rats and human beings.

Richter, C.P. & Clisby, K.H. (1941)

Proc. Soc. exp. Biol. Med. 48 684

Greying of the hair produced by ingestion of phenylthiocarbamide.

Richter, C.P. & Clisby, K.H. (1942)

Archs Path. 33 46

Toxic effects of the bitter tasting phenylthiocarbamide.

Riddell, W.J.B.(1941-42)

Ann. Eugen. 11 245

Classification of eye colour.

Riddell, W.J.B., & Wyber, K.C. (1944)

Nature 154 669

Taste of thiouracil and PTC.

Rife, C.D. (1938)

J. Hered. 29 83

Genetic studies of monozygotic twins.

Rife, D.C. (1940)

Genetics 25 178

Handedness with special references to twins.

Rife, D.C. (1943)

Genetics 28 41

Genetic interrelationship of dermatoglyphics and functional handedness.

Rife, D.C. (1950)

Hum. Biol.22 136

An application of gene frequency analysis to the interpretation of data from twins.

Rife, D.C. (1955)

Am. J. hum. Genet. 7 170

Handprints and handedness.

Rife, D.C. & Schonfeld, M.A. (1944)

Hum. Biol. 16 172

A comparison of the frequencies of certain genetic traits among gentile and Jewish students.

Roberts, J.A. (1942)

Nature 149 138

Surnames and blood groups with a note on a probable remarkable difference between North and South Wales.

Roberts, L. (1955)

Trans. Am. neurol. Ass. 80 143

Handedness and cerebral dominance.

Rodgers, P.V. (1946)

Proc. Soc. exp. Biol. Med. 63 38

Relation between sex hormones and changes in susceptibility of domestic Norway rats to ANTU poison.

Rohde, R.A. & Berman, N. (1963)

Lancet 2 1169

The Lyon hypothesis and further postulates.

Romanus, T. (1965)

Acta Genet. med. Gemell 14 417

The ability to taste PTC among Swedish men and women.

Roos, M.M. (1935)

Child Dev. 6 91

A study of some factors entering into the determination of handedness.

Rosler, H.D. (1957)

Int. Z. angew. Physiol. 16 434

Finger längenproportion und Handarbeit.

Rostrand, J. & Tétry, A. (1965)

An Atlas of Human Genetics

Hutchinsons.

Rozprym, T. (1934)

J. R. anthrop. Inst. 64 353

Eyebrows and eyelashes in man. Their different forms, pigment and heredity.

Rubin, T.R., Griffin, F. & Fischer, R. (1962)

Nature 195 362

A physico-chemical treatment of taste thresholds.

Rychkov, J.G. & Borodina, S.R. (1969)

Genetika 5 116

Hypersensitivity to phenylthiourea (PTC) in one of isolated population in Eastern Siberia. Possible hypothesis of inheritance.

Saldanha, P.H. (1956)

Lancet 2 74

Apparent pleiotropic effects of genes determining taste thresholds for phenthiourea.

Saldanha, P.H. (1958)

Ann. hum. Genet. 22 388

Taste thresholds for phenylthiourea among Japanese.

Saldanha, P.H. (1962a)

Hum. Biol. 34 179

Taste sensitivity to phenylthiourea among Brazilian negroes and its bearing on the problem of white/negro intermixture in Brazil.

Saldanha, P.H. (1962b)

Acta. Genet. med. Gemell. 11 158

The genetic effects of immigration in rural community of São Paulo, Brazil.

Saldanha, P.H. , Frota-Pessoa, O. & Peixoto, L.I.S. (1962)

J. Hered. 53 296

On the genetics of betanin excretion.

Saldanha, P.H. & Guinsberg, S. (1961)

Hum. Biol. 33 237

Distribution and inheritance of middle phalangeal hair in a white population of São Paulo, Brazil.

Saldanha, P.H., Magalhães, L.E., & Horta, W.A. (1960)

Nature, 187 806

Race differences in the ability to excrete beetroot pigment. (betanin).

Saldanha, P.H. & Nacrur, J. (1963)

Am. J. phys. Anthrop. 21 113

Taste thresholds for phenylthiocarbamide among Chileans.

Salgana, F.M. (1963)

Eugen. Q. 10 81

Population differences in red and green colour vision deficiency: a review and a query on selection relaxation.

Sammalisto, L. (1961)

Acta genet. Statist. med. 11 251.

The determination of zygosity in a study of Finnish twins.

Sanghvi, L.D. & Khanolkar, U.R. (1950)

Ann. Eugen. 15 52

Data relating to 7 genetical characters in six endogamous groups in Bombay.

Sarkar, S.S. & Ghosh, R.R. (1963)

Lancet I 1432

Hairy pinnae in the Bengalese female.

Scarr, S. (1968)

Eugen. Q. 15 34

Environmental bias in twin studies.

Scarr, S. (1969)

Soc. Biol. 16 249

Effects of birth weight on later intelligence.

Scheinfeld, A. (1965)

Your Heredity and Environment

Chatto & Windus, Ltd.

Scheline, R.R., Smith, R.L. & Williams, R.T. (1961)

J. mednl. pharm. Chem. 4 109

Metabolism of arylthioureas II. Metabolism of ^{14}C and ^{35}S labelled 1-phenyl-2-thiourea and its derivatives.

Schmidt, I. (1955)

J. opt. Soc. Am. 45 514

Some problems related to testing colour vision with the Nagel anomaloscope.

Schoenfeldt, L.F. (1969)

Human Hered. 19 343

A comparison of two analytic procedures for estimating twin zygosity.

Schreider, E. (1964)

<u>Yearb. phys. Anthrop.</u> 184

Investigations in social stratification of biological characters.

Schreider, E. (1968)

<u>Am. J. phys. Anthrop.</u> <u>28</u> 223

Body-height relative variation studied on 839 adult male samples.

Schreider, E. (1969)

<u>Am. J. phys. Anthrop.</u> <u>30</u> 215

Inbreeding biological and mental variations in France.

Schull, W.J., Yanase, T. & Memoto, H. (1962)

<u>Hum. Biol.</u> <u>34</u> 271

Kuroshima: the impact of religion on an island's genetic heritage.

Scott, J.A. (1961)

<u>Report on the Heights and Weights and Other Measurements of School Pupils in the County of London in 1959</u>

London County Council.

Scott, J.A. (1962)

<u>Br. J. prev. soc. Med.</u> <u>16</u> 165

Intelligence, physique and family size.

Scrimshaw, N.S., Balsam, A & Arroyave, G. (1954)

<u>Am. J. clin. Nutr.</u> <u>5</u> 629

Serum chloresterol levels in schoolchildren from 3 socio-economic groups.

Seefelt, E.R. (1964)

Am. J. Optom. 41 371

An evaluation of the validity and reliability of the AOC 15 plate pseudoisochromatic test in routine testing.

Seibert, H.C. & Steggarda, M.(1943)

J. Hered. 34 345

Age and hair form.

Seigel, S. (1956)

Nonparametric Statistics for the Behavioural Sciences.

International Student Edition,
McGraw Hill Book Co., Inc.

Seth, P.K., Seth, S., Rao, M.B. & Mani, S.B. (1969)

Human Hered. 19 190

Genetical study of the Gujars.

Setty, L.R. (1961)

Am. J. phys. Anthrop. 19 285

The distribution of chest hair in Caucasoid males.

Setty, L.R.(1962)

Am. J. phys. Anthrop. 20 365

Hair patterns on the backs of white males.

Setty, L.R. (1964)

Am. J. phys. Anthrop. 22 143

The distribution of hair on the upper limb in Caucasoid males.

Setty, L.R. (1966a)

Am. J. phys. Anthrop. 24 321

The distribution of anterior cervical hair in white and negro males.

Setty, L.R. (1966b)

Am. J. phys. Anthrop. 25 131

A comparative study of the distribution of hair of the hand and the foot of white and negro males.

Setty, L.R. (1969)

Am. J. phys. Anthrop. 31 153

Hair patterns of the pinna of white and negro males.

Sewall, K.W. (1939)

Am. J. phys. Anthrop. 25 93

Blood grouping, taste, digital hair and colour of eyes of eastern Eskimos.

Sheba, C., Adam, A. & Bat-Miriam, M. (1962)

Am. J. phys. Anthrop. 20 167

A survey of some genetical characters in Ethiopian tribes.

Sheba, C., Ashkenazi, I. & Szeinberg, A. (1962)

Am. J. hum. Genet. 14 44

Taste sensitivity to phenylthiocarbamide among the Jewish population groups in Israel.

Sheldon, W.H. (1954)

Atlas of Men.

pub. Harper, New York.

Shepard, T.H. & Gartler, S.M. (1960)

Science 131 929

Increased incidence of non-tasters of phenylthiourea among congenital athyreotic cretins.

Shields, J. (1962)

Monozygotic Twins

Oxford University Press.

Shuttleworth, F.K. (1940)

Hum. Biol. 12 280

Good and poor years for the growth of girls in stature and body weight.

Singh, G. (1968)

A Manual of the Multiple Variate Counter.

pub. University of London Computing Service.

Singh, S. (1967)

Acta genet. Statist. med. 17 348

Dermatoglyphics in schizophrenia.

Singleton, W.R. & Ellis, B. (1964)

J. Hered. 55 261

Inheritance of red hair for 6 generations.

Skude, G. (1959)

Hereditas 45 597

On sweet taste perception for phenylthiourea.

Skude, G. (1960a)

Acta Genet. med. Gemell. 9 325

Consistency of sweet taste perception for PTC.

Skude, G. (1960b)

Acta Genet. med. Gemell. 9 99

On sweet taste perception for PTC.

Slataper, F.J. (1950)

Archs Ophthal. N.Y. 43 466

Age norms of refraction and vision.

Slater, E. (1963)

Acta psychiat. neurol. scand. 39 78

Diagnosis of zygosity by fingerprints.

Slater, P., Shields, J. & Slater, E. (1964)

J. med. Genet. I 42

A quadratic discriminant of zygosity from fingerprints.

Slatis, H.M. (1964)

Cold Spring Harb. Symp. quant. Biol. 29 61

The study of normal variation in man II.

Slatis, H.M., & Apelbaum, A. (1963)

Am. J. hum. Genet. 15 74

Hairy pinnae in Israeli populations.

Smith, R.L. & Williams, R.T. (1961a)

J. mednl pharm. Chem. 4 97

The metabolism of arylthioureasI. The metabolism of 1.3-diphenyl-2-thiourea (thiocarbanilide) and its derivatives.

Smith, R.L. & Williams, R.T.(1961b)

J. mednl. pharm. Chem. 4 137

The metabolism of arylthioureas III. (a) the toxicity of H_2S in relation to that of phenylthiourea. (b) the protection of rats against the toxic effects of phenylthiourea with 1-methyl-1-phenylthiourea.

Soltan, H.C. & Bracken, S.E. (1958)

J. Hered. 49 280

The relation of sex to taste reactions.

Sorsby, A. (1964)

J. med. Genet. I 47

Statistical note on the components of ocular refraction in twins.

Sorsby, A. (1970)

Ophthalmic Genetics.

Butterworth, London, 2nd edn.

Spearman, R.I. & Barnicot, N.A. (1960)

Am. J. phys. Anthrop. 18 91

A study of the bilaterality of human hair.

Spies, T.D., Dreizen, S., Snodgrasse, R.M., Arnett, C.M. & Webb-Peploe, H. (1959)

Am. J. Dis. Child. 98 187

Effect of dietary supplement of non-fat milk on human growth failure.

Spuhler, J.N. (1950)

Cold Spring Harb. Symp. quant. Biol. 15 175

Genetics of 3 normal morphological variations: pattern of superficial veins of the anterior thorax, petronius tertius muscle and number of vallate papillae.

Srivastara, R.R. (1964)

East. Anthrop. 17 19

Further data on non-tasters among the Tharus of the Uttar Pradesh.

Srivastara, A.C. (1966)

East. Anthrop. 19 241

A note on the distribution of middle phalangeal hair among the Srivastaras of Lucknow.

Stafford, R.E. (1969)

Human Hered. 19 601

The case for nonparametric statistics in the analysis of twin data.

Standard, K.L., Lovell, H.G. & Harvey, L. (1966)

Br. J. prev. soc. Med. 20 135

Heights and weights of Barbadian schoolchildren.

Steggarda, M. (1941)

J. Hered. 32 402

Change in hair colour with age.

Steggarda, M. & Seibert, H.C. (1941)

J. Hered. 32 315

Size and shape of head hair from 6 racial groups.

Stein, L. (1952)

Br. J. soc. Med. II 181

"Social Class" gradient in schizophrenia.

Stern, C., Centerwall, W.R. & Sarkar, S.S. (1964)

Am. J. hum. Genet. 16 455

New data on the problem of Y linkage of hairy pinnae.

Stern, C. & Tokunaga, C. (1965)

J. Hered. 56 218

Hairy ear rims in Japanese.

Stewart, A. (1955)

Br. J. prev. soc. Med. 9 159

A note on the obstetric effects of work during pregnancy.

Stiles, K.A. & Schalk, J. (1945)

J. Hered. 36 211

A pedigree of curved forefingers.

Stoddard, S.E. (1939)

J. Hered. 30. 543

The inheritance of 'natural bangs'.

Stone, P.G. & Jones, P.R.M. (1968)

Ergonomics II 35

The magnitude and intercorrelation of 3 foot measures, height and weight of male students.

Sturkie, P.D. (1941)

J. Hered. 32 232

Hypermobile joints in all descendants for two generations.

Sunderland, E. (1955)

Ann. hum. Genet. 20 312

Hair colour variation in the United Kingdom.

Sunderland, E. (1965)

Nature 208 412

Hair colour of the population of Tristan da Cunha.

Sunderland, E. (1966)

Eugen. Rev. 58 143

The tasting of PTC in selected populations in the United Kingdom.

Sunderland, E. (1967).

Hum. Biol. 39 65

The skin colour of the people of Azraq, Eastern Jordan.

Sunderland, E. & Ryman, R. (1968)

Am. J. phys. Anthrop. 28 339

PTC thresholds, blood factors, colour vision and fingerprints of Jivaro Indians in Eastern Ecuador.

Sutton, H.E. (1965)

<u>An Introduction to Human Genetics</u>

Holt Rinehart & Winston.

Sutton, H.E., Clark, P.J. & Scholl, W.J. (1955)

<u>Am. J. hum. Genet.</u> <u>7</u> 180

The use of multi allele genetic characters in the diagnosis of twin zygosity.

Sutton, H.E., De Lamadrid, E.G. & Esterer, M. (1962b)

<u>Am. J. hum. Genet.</u> <u>14</u> 64

The hereditary abilities study: genetic variation in human biochemical traits.

Sutton, H.E., Vandenberg, S.G. & Clark, P.J. (1962a)

<u>Am. J. hum. Genet.</u> <u>14</u> 52

The hereditary abilities study: selection of twins, diagnosis of zygosity and program of measurements.

Swanson, A.B. & Brown, K.S. (1962)

<u>J. Hered.</u> <u>52</u> 259

Hereditary triphalangeal thumb.

Swanson, R. & Benton, A.L. (1955)

<u>Child Dev.</u> <u>26</u> 123

Some aspects of the genetic development of right-left discrimination.

Sweeney, D.R., Zegers, R.T. & Collins, W.E. (1964)

<u>J. soc. Psychol.</u> <u>62</u> 85

Color blindness in male negro children.

Tanner, J.M. (1962)

<u>Growth at Adolescence</u>

2nd Edn. Blackwell Scientific Publications, Oxford.

Tanner, J.M. (1966)

Eugen. Rev. 58 122

Galtonian eugenics and the study of growth.

Tanner, J.M., Whitehouse R.H. & Takaishi, M. (1966)

Archs Dis. Childh. 41 454

Standards from birth to maturity for height, weight, height velocity and weight velocity in British children 1965 Part I.

Taylor, C.W. (1961)

Hum. Biol. 33 220

A note on differential taste responses to phenylthiocarbamide.

Terry, M.C. & Segall, G. (1947)

J. Hered. 38 135

The association of taste-blindness and diabetes.

Thomson, A.M. (1959)

Eugen. Rev. 51 157

Maternal stature and reproductive efficiency.

Thomson, A.M., Billewicz, W.Z. & Holliday, R.M. (1967)

Br. J. prev. soc. Med. 21 137

Secular changes in the physique of Aberdeen mothers 1950-64.

Tiwari, S.C. & Bhasin, M.K. (1969a)

Am. J. phys. Anthrop. 31 429

A note on the distribution of mid-phalangeal hair among Tibetans.

Tiwari, S.C. & Bhasin, M.K. (1 69b)

Human Hered. 19 658

Freq ency of hand clasping and ear lobe attachment in Tibetans.

Topps, G., Cook, J., Holland, W.W. & Elliott, A. (1970)

Br. J. prev. soc. Med. 24 154

Influence of environmental factors on height and weight of schoolchildren.

Torgerson, J. (1950)

Am. J. hum. Genet. 2 361

Situs inversus, asymmetry, and twinning.

Torgerson, J. (1951)

Am. J. phys. Anthrop. 9NS 441

Hereditary and Environmental factors in twinning.

Trankell, A. (1955)

Am. J. hum. Genet. 7 264

Aspects of genetics in psychology.

Tripathy, K.C. (1963)

East. Anthrop. 16 133

Middle phalangeal hair along the Saoras of Puri, Orissa.

Trotter, M. (1930)

Am. J. phys. Anthrop. 14 433

The form, size and colour of head hair in American whites.

Trotter, M. (1939)

Am. J. phys. Anthrop. 25 237

Classification of hair colour.

Tse-Tung, Mao, (1966).

Quotations from Chairman Mao Tse-Tung.

Foreign Language Press, Peking.

Van Valen, L. (1963)

Nature 198 808

Natural selection in man.

Vandenberg, S.G. (Ed.) (1965)

Methods and Goals in Human Behaviour Genetics.

Academic Press.

Vandenberg, S.G. & Kelly, L. (1964)

Acta Genet. med. Gemell. 13 266

Hereditary components in vocational preferences.

Vandenberg, S.G., McKuisick, V.A. & McKuisick, A.B. (1962)

Nature 194 505

Twin data in support of the Lyon hypothesis.

Venning, P. (1956)

Am. J. phys. Anthrop. 14 1

Skeletal variations of the toes.

Verkade, P.E., Wepster, B.M. & Stegerhoek, L.J. (1959)

Acta Genet. med. Gemell. 8 361

Investigation on taste blindness with thiocarbamides.

II. Intra-pair discrepancy in pairs of identical twins.

Vernall, D.G. (1963)

Am. J. phys. Anthrop. 21 489

A study of the density of pigment granules in hair from four races of men.

Vernon, P.E. & Straker, A. (1943)

Nature 152 690

Distribution of colour blind men in Great Britain.

Vics, I.I. (1966)

Am. J. Optom. 43 582

A clinical evaluation of colour testing and colour perception.

Vollmer, H. (1937)

Archs Pediat. 54 574

The shape of the ear in relation to body constitution.

Wald, G. (1966)

Proc. natn. Acad. Sci. U.S.A. 55 1347

Defective colour vision and its inheritance.

Walls, G.L. (1955)

Am. J. Ophthal. 39 8

A branched pathway schema for the colour vision system and some of the evidence for it.

Walsh, R.J. & Chapman, R.E. (1966)

Man 1 NS 226

A study of the quantative measurement of human hair fibres.

Warkany, J., Guest, G.M. & Cochrane, W.A. (1955)

Am. J. Dis. Child. 89 689

Discordant monozygotic twins.

Warren, C.O. (1945)

Science 102 175

The effect of thiouracil on the respiration of bone marrow and leucocytes in vitro.

Warren, R.M. & Pfaffman, C. (1959)

J. appl. Physiol. 14 40

Suppression of sweet sensitivity by potassium gynemate.

Weiss, E.S. & Murray, L.J. (1966)

Ann. hum. Genet. 29 305

The frequency of iris bicolour in a school population.

Wheatcroft, P.E.J. (1967)

unpublished data - undergraduate project.

Human polymorphism: its distribution by social class.

Whitacre, J. & Grimes, E.T. (1959)

Child Dev. 30 177

Some body measurements of native born white children of seven to fourteen years in different climatic regions of Texas.

Whitney, D.D. (1939)

J. Hered. 30 323

Three generations of ear pits.

Whitney, D.D. (1949)

J. Hered. 40 18.

Tongue tip overfolding.

Widdowson, E.M. & McCance, R.A. (1944)

Lancet 2 152

Growth at home and at school.

Widstrom, G. & Henschen, A. (1963)

Scand. J. clin. Lab. Invest. 15 suppl.19 257

The relation between PTC taste response and protein bound iodine in serum.

Wiener, A.S. (1932)

Am. Nat. 66 365

Observations on the manner of clasping the hands and folding the arms.

Wiener, A.S. (1937)

J. Hered. 28 425

Complications in ear genetics.

Wiggers, C.J. (1949)

Physiology in Health and Disease.

Philadelphia Press.

Willerman, L. & Churchill, J.A. (1967)

Child Dev. 38 623

Intelligence and birth weight in identical twins.

Williams, R.H., Kay, G.A. & Jandorf, B.J. (1944)

J. clin. Invest. 23 613

Thiouracil, its absorption, distribution and excretion.

Williams, R.J. (1931)

Science 74 597

"Taste deficiency" for creatine.

Winchester, A.M. (1966)

Genetics

3rd Edn. Houghton Mifflin.

Wolff, O.H. (1955)

Q. Jl. Med. 24 NS 109

Obesity in childhood: a study of the birth weight, the height and the onset of puberty.

Woo, T.L. (1928)

Biometrika 20 79

Dextrality and sinistrality of hand and eye. Second memoir.

Woo, T.L. & Pearson, K. (1927)

Biometrika 19 165

Dextrality and sinistrality of hand and eye.

Workman, P.L., Blumberg, B.S. & Cooper, AJ. (1963)

Am. J. hum. Genet. 15 429

Selection, gene migration and polymorphic stability in a U.S. white and negro population.

Wyslouchowa, B. & Orczykowska, Z. (1969)

Acta Med. pol. 10 187

The diagnosis of twin zygosity on the basis of blood group studies.

Wyszecki, G. & Stiles, W.S. (1967)

Colour Science

John Wiley Inc., N.Y.

Yerushalmy, J. & Sheerar, SE. (1940)

Hum. Biol. 12 95

Studies on twins I: the relation of the order of birth and age of parents to the frequency of like-sexed and unlike-sexed deliveries.

Young, M. & Gibson, J. (1963)

Br. J. statist. Psychol. 16 27

In search of an explanation of social mobility.

Yudkin, J. (1944)

Br. med. J. 2 201

The nutritional status of Cambridge schoolchildren.

Zieve, I., Wiener, A.S. & Fries, J.H. (1936)

Ann. Eugen. 7 163

On the linkage relations of the genes for allergic disease and the genes for determining the blood group types and eye colour in man.

Private communications

McConnell, R.B. (1968)

Department of Medicine, University of Liverpool.

Method of testing for secretor status.

Ministry of Labour, Birmingham (1968)

Employment statistics.