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RESEARCH IN POPULATION GENETICS OF PRIMITIVE GROUPS

Report of a WHO Scientific Group

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RESEARCH IN POPULATION GENETICS OF PRIMITIVE GROUPS

Report of a WHO Scientific Group

A meeting of a WHO Scientific Group on Research in Population Genetics of Primitive Groups was held in Geneva from 27 November to 3 December 1962. The meeting was opened by Dr F. Grundy, Assistant Director-General, who welcomed the participants on behalf of the Director-General. Dr J. V. Neel was elected Chairman ; Dr J. Guiart, Vice-Chairman ; and Dr N. A. Barnicot and Dr R. L. Kirk, Rapporteurs.

1. INTRODUCTION

Many of the primitive communities of the world face immediate disintegration of their culture, with consequent far-reaching biological changes. This presents a challenge to biomedical scientists which has an urgency and importance quite out of proportion to the relatively small number of people directly involved, or the known health problems concerned.

In the present report, the Scientific Group has attempted to outline the nature of this important problem and to suggest the way in which it may be approached through studies in the population genetics of long-standing, but now rapidly changing, human indigenous populations. Such studies will need to give special attention to the ecological and sociological factors bearing on the genetic structure of small populations, particularly those with a hunter-gatherer, simple pastoral, or digging-stick-and-hoe type of agricultural economy.

Although there is a substantial body of generally accepted theory regarding the factors that govern the distribution of genes in time and space, few groups, either primitive or civilized, have been fully described genetically. Still less have the biological and sociological parameters relevant to their genetic structure been adequately investigated.

The present emphasis on primitive communities of the types mentioned above springs from a number of considerations :

(*a*) Such groups present both in their size and level of economy the closest approximation one can find to the conditions under which man has lived for the greater part of his existence. It is probable that much

of the genetic endowment of modern man has been shaped by the action of natural selection and other evolutionary processes at these cultural levels.

(*b*) The relatively small size of these populations and the simplicity of their ecology render them more manageable for intensive studies than larger, more complex groups with their special problems of sampling.

(*c*) The majority of these populations are threatened with imminent cultural disintegration and, in some instances, loss of physical identity in the face of advancing civilization. It is therefore imperative to study them as fully and as soon as possible.

(*d*) The appropriate techniques for such intensive studies are now available.

The studies envisaged will require the close co-operation of specialists from many overlapping disciplines, including not only human geneticists, but also social, cultural and physical anthropologists, linguists, demographers, ecologists, geographers and medical scientists.

1.1 Objectives of studies

The study of population genetics in primitive groups should clarify the following problems:

(*a*) The genetic component in mortality and fertility differences, through the study of familial factors on the one hand, and the study of variations in birth- and death-rates in relation to different genetic structures on the other.

(*b*) The biological consequences of inbreeding. Such populations also provide opportunities for examining the biological consequences of formal kinship and marriage systems.

(*c*) The disease pattern of relatively undisturbed primitive populations. Attempts should be made to relate disease susceptibilities to specific genetic structures.

(*d*) The possible evolutionary implications of differing disease patterns in males and females.

(*e*) The biological relationship of the group under study to neighbouring groups or to those more remote in time or space. This is likely to require collaborative study involving, for example, cultural, anthropological, linguistic, historical and archaeological investigations.

(*f*) The effects of contact with more advanced cultures, in particular the effect on gene frequencies, the emergence of new disease patterns,

the possible relationship of these to genetic constitution, and the alteration in physical measurements and physiological and biochemical characteristics.

Such studies will involve the careful collection of a large amount of information by experts from many disciplines, both in the field and in the laboratory. The data which the Group considers should be collected in a carefully planned and co-ordinated investigation are set out below. It is realized that there are many factors that may make it difficult to assemble all this information for any particular group, such as lack of full rapport with the group under study (problems of language or other difficulties in communication) ; breakdown in the collection and transport of specimens ; limited availability of trained personnel or specialist facilities. The Group wished to emphasize, however, that every attempt should be made to carry out such studies as intensively as possible so that valuable information can be recorded before it is too late.

2. DATA TO BE COLLECTED IN STUDIES OF PRIMITIVE GROUPS

In a comprehensive study in which the genetic structure of a population is to be considered against the background of many ecological factors, both physical and social, it is desirable to set out systematically and in some detail the various kinds of information that will be needed. In the following pages an attempt has been made to do this, indicating in some instances which of many possible items are, in the Group's opinion, essential and which should be added only if circumstances are favourable.

No attempt has been made to give detailed recommendations for collecting such data, although it is recognized that methodology is of great importance if the results of different projects are to be comparable and are to be used to maximum advantage. Methods suitable for surveys of this kind should indeed be reviewed and a recommendation to this effect has been included at the end of this report.

2.1 Demography and socio-cultural environment

Individual records

In each community the following details should be recorded for each individual, including temporary absentees and recent emigrants :

(*a*) date and place at which record was taken ;

(*b*) name and social group affiliation (vernacular names should be given in standard phonetic form) ;

(*c*) sex ;

(*d*) age (as accurately as possible) ;

(*e*) birthplace (the detail in description depending on the community under study).

In addition to these items, the investigator should determine :

(*f*) The identification of every individual by residence and social position. Household or other nuclear residential unit should be indicated and also descent group membership and relation to group head. Difficulties in definition of household or other residential unit may arise but it is important to maintain consistency.

(*g*) The position of each individual in a genealogical matrix. The social anthropologist's attention will be directed to cultural variants : whether the system of kin terminology is of the classificatory rather than of a descriptive order ; whether there are taboos on names of the dead ; whether genealogies are used as instruments for land claims or status claims, which may cause them to be falsified. A special check will be needed on adoptions, which are frequent in many communities and which may not be readily recognized. The genealogies should give all live births and include the names of all recently dead persons, but they may be incomplete for persons who died some time previously and who produced no offspring. Serological and other genetic data can be used to check recorded genealogies, thereby revealing biological and social relationships.

Mating records

(*a*) Pregnancy history of each woman in the population.

(i) Total number of pregnancies and approximate age at each conception.

(ii) The outcome of each pregnancy (spontaneous or induced abortion, stillbirth or live birth), with indication of sex where possible ; special inquiry regarding multiple births.

(iii) Number of surviving children by sex, and number deceased, with ages at death.

Local attitudes, beliefs and customs (such as prudery or the belief that spirits of miscarriage and stillbirth can influence the health and welfare of the survivors) frequently make the collection of the above data extremely difficult.

(*b*) Paternity identification for each pregnancy.

(It is often inadvisable to attempt to elicit this information at the time that the pregnancy history is being taken.)

(*c*) When the above data have been collected it will be possible, if desired, to extract from them the following information :

(i) degree of consanguinity between partners ;
(ii) age at commencement of cohabitation ;
(iii) period of cohabitation ;
(iv) number of male and number of female children still living ;
(v) number of male and female children who have died, by age at death ;
(vi) number of male and female stillbirths ;
(vii) number of miscarriages.

Social factors affecting fertility and survival

The social anthropologist [1] can point to certain local peculiarities of custom that may have an important bearing on reproductive performance or on individual or group survival. Some of these can be directly observed and even recorded but in other cases they will be part of a more subtle knowledge of the culture.

Among these should be noted :

(*a*) Post-partum practices relating to mother, child and father, e.g., the father may have to observe a taboo on sexual intercourse until the child is weaned.

(*b*) Infant feeding : breast feeding or not ; pre-mastication ; lactation period ; weaning. Some special customs may be found, e.g., artificial stimulation of milk secretion in non-lactating females to feed neonates whose mothers have died. (This may be especially significant in small societies where lactating women may not always be available.)

(*c*) Differential nutrition within the family, e.g., men receiving the most protein-rich foods ; taboos on certain foods or fasting in response to mourning obligations ; special foods for adolescents ; differential use

[1] It should be realized that knowledge of the over-all social structure is necessary for the social anthropologist to provide minimal material on most of the topics mentioned not only here but in other contexts in this report. He needs, therefore, not only a familiarity with the vernacular but also a long period of study, possibly upwards of a year. Data on genealogies, marriage practice, etc. cannot be obtained in a brief period. Freedom should be allowed to the anthropologist in the collection of social data. The relevance of certain social data to the genetic studies or *vice versa* may emerge in the course of co-operative work although their importance could not have been foreseen.

A linguist will be a valuable and often indispensable member of the team. Where the language of the people is not already known his skills may be needed to elucidate its structure, vocabulary and semantics. In addition, he may undertake comparative studies of phonetic distribution or of glottochronology which may yield interesting generalizations to set against the genetic information.

of intoxicant or stupefying substances that may affect mating frequency, e.g., peyote, kava, betel. Collection of these data needs co-operation with ecologists, nutritionists and biochemists. There are few research workers with training in both nutrition and social anthropology; such training should be encouraged.

(*d*) Pre-marital relations between the sexes.

(*e*) Marriage patterns and their variants, with special reference to preferential mating, e.g., prescribed marriage, as with mother's brother's daughter.

(*f*) Breach of marriage rules, i.e., extra-marital mating.

(*g*) Factors influencing population number, such as sterility, induced abortion, and infanticide, merit special attention.

(*h*) Attitudes towards special physical characters as mating determinants, e.g., in some cultures albinos and persons suffering from certain skin diseases or mental abnormalities may not be chosen as marriage partners nor have other opportunity to breed.

(*i*) The pattern of sexual intercourse may be related to social activities, e.g., there may be taboos on intercourse before hunting, before going on an expedition, etc.

(*j*) The fatal hazards of war, hunting, etc., by selectively reducing one sex, will influence the mating pattern of the community.

(*k*) In some cases, for example nomadic hunting bands, the type of leadership or authority may affect the survival of the group or at least of the more vulnerable sections of it, and may even be relevant to its genetic structure.

2.2 Health status and disease pattern

The aims of the medical investigations are to determine the main present and past causes of death and morbidity in the population and to evaluate the current health status of persons of all ages in the community. Particular attention should be given to congenital abnormalities and to nutritional status.

Medical histories, examinations, and laboratory investigations should be as thorough as possible; it should be noted that a variety of new tests are now available which can be used under field conditions and in the laboratory. The data considered essential to a genetic study of a primitive population are outlined below. Circumstances may permit a more comprehensive health study; this list will then need to be expanded appropriately.

Medical history

This is important not only for individuals but for the entire social group. Information may be obtained from :

(*a*) the recollections of the subjects studied, and from shamans or old informants ;

(*b*) outside observers, e.g., government officials, traders, and local medical personnel, or from regional and area medical records, etc. ;

(*c*) examination of dead bodies, either of skeletal and dental remains. or of tissues naturally preserved by desiccation, freezing or chemical action.

Physical examination of all individuals

(*a*) routine clinical observations, including ophthalmoscopy, visual acuity tests, otoscopy, blood pressure, dermatological (noting keloids and cicatrices), nutritional and neurological examinations ;

(*b*) reproductive status, including evaluation of lactation efficiency, effects of pregnancy ;

(*c*) dental and stomatological examination, including caries index and dental abrasion ;

(*d*) special tests (to be done on selected individuals or in case of specific disease indications) :

skin testing (tuberculin, atypical mycobacterium tuberculins, histoplasmin, blastomycin, coccidioidin, trichinella and ecchinococcus antigens, Schick tests and appropriate hypersensitivity allergens) ;

microbial isolation studies (bacterial, leptospiral, viral, rickettsial, protozoal and fungal, including sero-identification of specimens) ;

(*e*) tests requiring specialized facilities in the field :

X-ray ; electroencephalogram, electrocardiogram, electromyogram ; pulmonary function studies ; metabolic disease investigations (renal, hepatic, nutritional and endocrine functions) ; tensiometer studies for glaucoma.

Laboratory investigation

(*a*) On all subjects :

haematological studies (complete blood count, sickling preparation, thick and thin smears) ;

serum biochemistry (proteins, cholesterol, non-protein nitrogen, serum iron ; in special cases, electrolyte, endocrine, liver function and nutritional estimations) ;

sero-epidemiology (bacterial, rickettsial, viral, fungal, helminthic, protozoal, spirochaetal, leptospiral and auto-immune antibodies) ;

urine (routine clinical urine analysis; in special cases total iodine, electrolyte and hormone analysis);

faeces (benzidine test and examination for ova);

(*b*) Special tests on selected subjects involving analysis of saliva, sweat, nasal smears, cerebrospinal fluid and microbial cultures.

(*c*) Many screening tests for intermediate metabolites, such as carbohydrates, amino-acids, phenylpyruvic acid, uric acid, steroids, etc., may be done on serum and urine specimens as facilities permit.

Pathology

Examination of material from:

(*a*) autopsies;

(*b*) biopsies;

(*c*) burial remains.

In addition to the examinations listed above, no medical study of a community can be complete without continuous surveillance or, failing this, periodic follow-up examinations. Experience already gained in work with primitive populations has indicated the importance of such follow-up studies, which in some cases have led to a complete revision in the listing of the major causes of death in the community.

2.3 Genetic and other physical data

Four somewhat arbitrary categories are used here:

A. Serological and biochemical genetics.

B. Other genetic characters.

C. Morphology.

D. Physiology.

It will be obvious that the first category comprises a number of simply inherited variations which are detected by biochemical or serological methods. Under morphology are included various measurements of gross bodily size and shape which, although determined by genes to a varying extent, cannot at present be genetically analysed in detail. These morphological characters are of interest not only to geneticists but often to nutritionists, students of growth, and anthropologists interested in the comparison of populations by traditional methods. It may be most convenient to make some of the observations listed in this section in the course of the medical examination.

A. SEROLOGICAL AND BIOCHEMICAL GENETICS

Tests on Blood

(*a*) *Blood group antigens*

Genetic system	*All series*	*Selected series*	*Series specially selected as justifying the use of very rare reagents*
ABO	A_1 A_2 B H		
MNSs	MNS	s He Vw	Hu ? St^a M^g
P	P_1		P^k
Rh	C D D^u E c e	C^w Ce E^w V(ce^s)	C^u, C^x, CE, E^u, e^s, e^i
Lutheran		Lu^a Lu^b	
Kell	K	k Kp^a	Kp^b
Lewis	Le^a Le^b		
Duffy	Fy^a		Fy^b
Kidd		Jk^a	Jk^b
Diego		Di^a	
Sutter		Js^a	Js^b
Auberger			Au^a
Xg			Xg^a
Wright		Wr^a	

(*b*) *Enzymes*

All series	*Selected series*
Glucose-6-phosphate-dehydrogenase	Esterases (including carbonic anhydrase)
	Catalase

(*c*) *Haemoglobins*

All series

Electrophoretic studies employing several supporting media, such as starch gel, cellulose acetate, or paper.

Estimation of haemoglobin-A_2 levels.

Tests on Serum

(*a*) *Serum groups*

All series

Haptoglobins
Transferrins
Group specific components (Gc)
Gm and InV groups

(*b*) *Enzymes*

All series : Pseudocholinesterase

(*c*) *Antibodies*

All series : Routine screening for blood-group antibodies, including tests with control cells from population being examined. In many cases, it may be desirable to carry out tests for auto-immune antibodies at this stage.

Tests on Saliva

All series	*Selected series*
Secretor status ABH	Titration of A,B,H
Secretor status Le^a and Le^b	Titration of Le^a and Le^b

Tests on Urine

Selected series

Amino-acid patterns including β-aminoisobutyric acid

Tests Not Yet Fully Developed but Possibly of Future Importance

Serum Ag groups
Lactic dehydrogenase
Malic dehydrogenase
Antigens of platelets and leucocytes

B. OTHER GENETIC CHARACTERS

Cytogenetic Studies

The examination of buccal smears for sex-chromatin and of blood-culture cells for major changes in the karyotype could be envisaged for

the whole population in some cases. More detailed observations on cells cultured from skin biopsies might sometimes be desirable on smaller numbers of subjects.

Colour Blindness

To be recorded by Ishihara or other charts or, if possible, using more sophisticated apparatus, such as the anomaloscope.

Ability to taste Phenylthiocarbamide (PTC)

When possible, full-scale solution sorting tests should be used, but these may present difficulties unless communication with the subjects is good.

C. MORPHOLOGY

Measurements of Body Dimensions

The following should certainly be included and may in many cases be considered sufficient:

(*a*) *Weight*

(*b*) *Linear measurements*

cranial	*postcranial*
maximum length	total height
maximum breadth	sitting height
bizygomatic breadth	biacromial breadth
total face height	intercristal breadth
upper face height	bicondylar humeral breadth

(*c*) *Circumferential measurements*

mid-arm	mid-thigh
forearm	calf
wrist	chest

(*d*) *Measurement of skin folds*

posterior arm infrascapular iliac

The measurements listed above should be obtained in the field with calipers, tape or scales, but standardized photographs should be taken for laboratory analysis of other metric characters. Radiographs, for example of the wrist or calf, may sometimes be desirable.

Dental Studies

Direct observations, supplemented by casts and radiographs if possible.

Studies on Pigmentation

(*a*) *Skin*. Measurements should be taken by reflectance spectrophotometry on the medial side of the arm, flexor surface of forearm and the forehead.

(*b*) *Hair*. Samples of head hair should be collected for spectrophotometric examination, study of hair form, etc.

(*c*) *Eyes*. For most of the populations listed later in the report, eye colour is not likely to vary significantly. If required, approximate records can be obtained with a standard scale.

Dermatoglyphics

Digital and palmar prints should be obtained and perhaps prints of the toes and the sole in special cases.

D. PHYSIOLOGY

Various physiological observations, such as pulse rate and blood pressure, will have been made during the medical examination.

Extensive studies on, for example, physiological adaptation to heat or cold, would require more personnel, equipment and time than will generally be available, though they might be contemplated in certain instances.

2.4 Data on physical and biological environment

No investigation of the population genetics of a group will be complete without a reasonably detailed study of the physical and biological environment. The scope of such a study will depend on the material and human resources available, but every attempt should be made to carry out the investigation in conjunction with well-trained climatologists, botanists and zoologists.

Climatological and geological studies

(*a*) Standard meteorological observations with attention to microclimatology.

(*b*) Soil survey.

(*c*) Geological and topographical survey, aerial photographs of terrain.

In many areas there is a deficiency of adequate maps for proper identification of localities, etc. Whenever possible, the aid of a cartographer should be enlisted at an early stage of the investigation.

Botanical studies

(*a*) An ethnobotanical survey, including cultivated and gathered foods, medicinal plants, vegetable body paints, etc.; species identification of relevant plants is important.

(*b*) Yield studies and nutritional evaluation of food plants.

(*c*) Habitat survey : type and distribution of cover in relation to human activity and zoology (disease vectors and hunted animals).

Zoological studies

(*a*) An ethnozoological survey, including domestic animals and their diseases, body parasites, and animal foods; species identification of all relevant animals is important.

(*b*) Nutritional analysis of animal foods.

(*c*) An ecological survey of local fauna.

(*d*) A medical entomological survey.

3. POPULATIONS SUITABLE FOR INVESTIGATION

Populations considered suitable for study are set out below under the 5 broad regional headings : (*a*) the Arctic, (*b*) South America, (*c*) Africa, (*d*) Asia, (*e*) Australasia (including South Pacific islands).

In each area prominence has been given to a small number of populations the study of which is felt to be particularly important, and which for one reason or another are considered to merit priority. Some suitable groups may have been overlooked, and others may not be known at present. In general, those selected have been chosen because they are still hunter-gatherers or primitive agriculturalists and have not, as far as known, been significantly affected by foreign gene penetration in recent times; in many instances, they are groups that are in grave danger of cultural extinction or serious decline in numbers. A few salient features of these high-priority groups have been indicated briefly. In addition, a number of other populations have been listed which are of less immediate interest.

(*a*) *The Arctic*

There is much information about Eskimo-Aleut peoples as a whole but individual isolates have rarely been studied in a comprehensive and

multidisciplinary manner. Although all these peoples have been in contact with Europeans, some for as long as two or three centuries, they are of peculiar interest from the point of view of population genetics because of their geographical distribution, their specialized ecological adaptation, and the considerable archaeological material available.

The *Thule Eskimos* (Inupik language group) are the most northerly community in the world and are a long-established, geographically confined breeding isolate of land hunters for which there are few blood-group or morphological data.

The *Nunivak Island Eskimos* (Yupik language group) are ecologically contrasted with the Thule, being more dependent on marine hunting.

Other populations of interest

Greenland : Angmassalik Eskimos

Canada : Baffin Island Eskimos
Labrador Eskimos

Alaska : King Island Eskimos
St Lawrence Island Eskimos
Interior groups
Kenai Peninsula Eskimos
Aleutian islands and peninsula (Belkofski, Akutan).

Certain neighbouring Indian populations are also of interest, notably the Tlingit, Haida, Tsimshian and Athabascans. In addition, the arctic or sub-arctic peoples of Siberia and northern Europe are of great interest and have been little studied ; these include the Chukchi, Koryak, Yukaghiv, Gilyak, Samoyed, Lapps and various peoples of undetermined affiliation.

(*b*) *South America*

The *Guayaki* are hunter-gatherers who roam the forests of eastern Paraguay in small bands. They speak an archaic form of Guarani and their language has already been recorded and studied as some 60 of them are now settled near Villa Rica. Although only these 60 are at present easily accessible, some 300-400 are believed to be still living in the forest.

The *Siriono* of Bolivia are perhaps related to the Guayaki ; they live under the same conditions and also speak a Guarani language.

Among various tribes of the Ge family in eastern and central Brazil, the *Kayapo* of Gorotire and Kubenkrankey might be given priority since they are most in danger of disappearing. All the Ge tribes practise some agriculture as well as hunting-gathering. Their social organization is the most complex in South America. They are easily accessible, and have already been studied by social anthropologists. Genetic studies have also been started among one of the most important tribes, the Chavantes.

The *Waika* of the Brazilian-Venezuelan border are mainly hunter-gatherers and although very isolated can be reached without difficulty. This population has already been studied anthropologically.

Other tribes that might be considered are : the Maku of the Rio Negro ; the Shiriana (Brazil and Venezuela) ; the Guahibo (Venezuela and Colombia) ; the Nambikuara (Mato Grosso) ; the Morotoko (Northern Chaco) ; and the Pakasnovas (Brazil, Bolivian border).

(*c*) *Africa*

The *Hadsa* (Tindiga) are hunter-gatherers, about 500 in number, in the lake Eyasi region of north Tanganyika, 24 hours by car from Nairobi. Their language contains clicks, but its relation to Sandawe and Bushman languages may be remote. A social anthropologist has recently been with them for three years.

Pygmies (Negrillos), especially those found in the Central African Republic and the Ituri forest zone of the Congo Republic, are hunter-gatherers who for the most part have economic and social relations with the neighbouring Bantu but still retain their own population structure.

Bergdamara is a general name for certain scattered groups in South West Africa who speak a Hottentot language but are of uncertain origin and cultural affinities. The most suitable groups for study live to the north-west and south of Windhoek. Some preliminary blood-group studies have been made.

The *Sandawe* of northern Tanganyika are a primitive pastoral group living in an area about 100 miles to the south-east of the Hadsa. They are believed by some anthropologists, on linguistic and morphological grounds, to have Hottentot affinities. There is some intermixture with Bantu.

The following groups are also worthy of attention : the Bushmen of the Caprivi strip and north-east of Makarikari Pan ; Dahalo and associated groups in north Kenya ; Batwa near Broken Hill, Northern Rhodesia ; selected groups of Nama-speaking Hottentots in south-west Africa ; certain groups in south-west Madagascar.

(*d*) *Asia*

The *Onges* of Little Andaman are a small, long-isolated, hunter-gatherer population which is now fast disappearing ; they are thought to number between 200 and 500. They are believed to be related to certain other Negrito peoples in widely separated parts of Asia.

The *Jarawa* who inhabit the jungles of south and middle Andaman are believed to be related to the Onges, though they differ considerably in language and culture from the virtually extinct tribes of Great Andaman. They are not easily accessible but favourable conditions may soon develop.

Punan is a general name given to certain small nomadic bands in the remote forest areas of Sarawak and the borders of Indonesian Borneo. A genetic and ecological study would be difficult but very interesting. At the same time the nomadic Penan (with whom they are sometimes confused) might be investigated. Their social anthropology has already been studied.

Among *other populations* of interest are Negritos of Malaya and Luzon ; Veddahs of Ceylon ; Chenchu, Kadar, Irula, Warli and Katkari of south and central India. The Ainu of Hokkaido and Sakhalin and the Todas of south India, though very interesting for genetic study, are not " primitive " groups in the same sense as those listed above.

(*e*) *Australasia (including Pacific islands)*

Australasia, including the South Pacific Islands, presents the largest number of primitive groups of any of the five regions reported, but, except for a few non-agricultural cultures in Borneo and New Guinea, only Australian Aborigines are entirely hunter-gatherers. The regions of Australasia and Oceania, however, afford an unusually wide range of ecological niches in which human populations evolved and wherein relatively primitive and genetically undisturbed groups may yet be studied. Although over 50 groups well suited for study could be cited in New Guinea, several dozen on Micronesian, Polynesian and smaller Melanesian islands and a few in Australia, recommendations are limited to one representative group from each of the following distinct ecological patterns : desert, New Guinea highland, New Guinea coastal lowland, atoll, small high island (malarious and non-malarious).

Australia. The Australian Aborigine groups inhabitating the Western Desert number 2000 to 3000 ; they remain in the area of the Warburton-Rawlinson and Peterman Ranges and north to Balgo in western Australia. They have had minimal contact with European culture, at any rate over part of their life ; however this situation is rapidly changing. Their study is therefore urgent.

New Guinea. The *Fore* of the eastern New Guinea highland number approximately 12 000 agriculturalists still at a low level of acculturation. They are particularly interesting because of the unique effect of kuru on their population genetics.

On the western coastal lowland, the *Asmat* number approximately 15 000. They are a sago-gathering and fishing people, who are only now, under government and mission influence, abandoning head-hunting raids and cannibalism. These people do very little walking, as they hunt and even gather sago from canoes.

Small island atoll : Nuguria. This Micronesian atoll community in the Bismarck Archipelago, consisting of approximately 200 inhabitants, has

escaped the outside influences that have touched in one way or another the rest of Micronesia and Polynesia.

Small, high islands, malarious zone : Tongariki. A small, high-island community (400 inhabitants) in the malarious zone whose social structure and economic life have remained stable ; it is composed of strong kava drinkers (influence of kava on the occurrence of sexual contacts). Anthropological studies have been carried out and archaeological investigations are planned for the immediate future.

Small, high islands, non-malarious zone : Anuta. This small, high, isolated island of Oceania with 170 inhabitants has escaped European contact, and is out of the malarious zone. Anthropological studies have been started.

There are many additional populations both in New Guinea and in the Pacific islands suitable for further study but they are too numerous to enumerate here.

4. RESEARCH DESIGN

Comprehensive studies of the kind recommended above, involving not only collaboration of many different specialists for varying periods but access to and work in relatively inaccessible parts of the world, demand careful attention in planning and execution.

A general guide for the organization of population genetic studies in primitive populations is set out below. No single scheme, however, will necessarily apply to every population listed. For some groups, for instance among the Eskimo populations of the Arctic or the aborigines of Australia, sufficient detailed knowledge of the cultural, linguistic, health and genetic structures is available already. For these, it will be possible to plan in detail a full investigation without either preliminary investigations or pilot studies.

At the other extreme, the study of populations such as the Kayapo Indians of South America or the Punans of Central Borneo will raise difficulties which will require the most careful consideration before even a pilot study can be recommended. The remaining populations fall between these extremes. For example the Onges of Little Andaman Island or the Bergdamara of Africa have been studied by social and cultural anthropologists, and some study of their genetic structure has also been undertaken. It is probable that a pilot study could be carried out among them without great difficulty. This, in turn, would provide the information necessary for the detailed planning of a full-scale study.

With these qualifications in mind, it is suggested that comprehensive studies should proceed in the following stages :

4.1 Preparatory studies

(*a*) Contact with the appropriate departments of the government in whose territory the population resides. This should be followed by establishing the most suitable channels of communication with administrative officers in the areas concerned.

(*b*) Contact with scientific personnel with previous or current experience of the population concerned.

(*c*) Collection of a complete bibliography and survey of relevant museum material.

(*d*) Formation of a group of experts to provide a nucleus of persons who will collaborate in the later stages of the project. This should include at least a human geneticist, medical scientist, social or cultural anthropologist, and a physical anthropologist.

(*e*) A preliminary visit to the area by one member of the group to establish personal contact and understanding with local administrative officials and the actual population. At this stage, the degree of linguistic contact must be assessed and an appraisal made of transport facilities and health hazards in the area of study.

4.2 Pilot studies

These would consist of preliminary compilation of cultural and social anthropological information, in addition to testing the facilities and arrangements for the collection of medical and genetic information.

Conditions vary widely in different populations ; as a guide, one may indicate, however, that a pilot investigation would require at least the equivalent of four man-months in the field. It is suggested that the team should include at least two persons from the group of specialists working on the project, with suitable supporting personnel.

4.3 Full-scale studies

In addition to the human geneticist, medical scientist, cultural or social anthropologist, and physical anthropologist, certain other experts will need to visit the area for varying periods of time. These may include the appropriate specialists in linguistics, dentistry, geography, ecology, geology, archaeology, zoology, botany, ornithology, medical entomology and agricultural science. Such studies will often extend for long periods, and may require repeated visits to the area, either to verify or to amplify previous observations.

Again, the time and effort required cannot be specified precisely. However, a full-scale study of the kind envisaged will probably require the equivalent of four persons in the field continuously for two years. In

addition provision should be made for one person to remain in the field for a further year to maintain contact with the group and facilitate repetition of some of the observations if necessary.

In organizing a full-scale study, attention must be given to the schedule of arrival and departure of investigators, in particular to the appropriate synchronization of visits (e.g., the presence of zoologists and medical entomologists in the area at the same time); to transport arrangements, both for personnel and specimens; and to assuring the co-operation of base laboratories. This last point is no less important than the others. No comprehensive study can be successful unless prior assurances are received that the material collected can be processed both accurately and expeditiously.

4.4 Follow-up studies

Although it is often impossible to guarantee sufficient financial support to enable a research programme to be continued for several years, it is important to realize that much valuable information can be collected from follow-up studies. This is true not only of cultural and social anthropology where patterns may change very rapidly, but also of medical, genetic, and physical anthropological studies as well.

5. EQUIPMENT AND OTHER FACILITIES

Comprehensive studies of the kind envisaged need adequate financial provision for equipment and specialized facilities of many kinds. In some areas, specialized equipment and laboratories offering particular techniques are already available. In others, such facilities will have to be set up or existing services expanded.

No attempt has been made here to list the routine equipment needed, either for pilot studies or full-scale investigations, but budgetary provision will be required for special items such as microwave radio transceivers, electricity generators, portable X-ray equipment, etc. Provision for specialized forms of transport—frequently expensive—should be given high priority. These include boats and outboard motors, 4-wheel-drive vehicles, and aircraft. Precise demands will depend on the area involved and the type of equipment already available.

In addition to these general considerations, there are some special problems that demand more detailed attention.

(a) Supplies of serological reagents

Most of the reagents used in blood grouping in the restricted sense and in the testing of serum for Gm and InV groups are made from human

serum, and some of these are exceedingly rare or even unique, so that the total amount of full testing that can be done throughout the world is severely restricted.

Some of the human reagents are in ample supply. Others, such as the Lewis antibodies, though scarce, are known to occur in the sera of apparently healthy persons, and maintenance of a supply depends upon the appropriate screening of the sera of large numbers of persons. This activity, which can best be done in large blood banks, needs active encouragement.

Other antibodies occur solely or mainly in the sera of persons who have become immunized by pregnancy or transfusion. It is important that contact be maintained with such persons. To achieve this (as well as many other aims mentioned) much can probably be done by giving encouragement to blood-group reference laboratories. Another possibility, although one upon which medical opinion is divided, is the artificial reimmunization of persons already immunized.

A few reagents are or can be prepared as animal or plant products. An increase in supplies of reagents for the detection of some antigens can probably be secured by further animal experiments or by the screening of further seeds and other vegetable tissues. There is probably little more to be done in immunizing rabbits with red-cell antigens, but it is likely that other animals and especially primates, now readily available for research purposes, would respond to certain antigens for which reagents have hitherto been obtainable only from very small numbers of human beings. Research to this end is recommended.

The immediate need is to secure the co-operation of the blood-grouping laboratories in all member countries in making available supplies of rare reagents.

(*b*) *Transport of specimens*

Detailed arrangements must be made in advance for every stage of transport, including change of aircraft at intermediate points, renewal of ice or solid carbon dioxide (between which a clear distinction must be made), customs clearance, and delivery to the laboratory. Specimens that must not be frozen, such as whole blood, must not travel in an unheated compartment of an aircraft, even in an insulated container.

Various arrangements may be made to ensure rapid delivery, for instance with the collaboration of diplomatic services and air forces of the countries concerned. It is also helpful if the receiving laboratory has long-standing personal arrangements for delivery of specimens with one or more international air transport companies. In general, however, the organizers of the survey will themselves need to make all arrangements, and in order to avoid administrative delays it is essential that consignments be given a special and unmistakable status by international agreement.

(*c*) *Selection of testing laboratories*

Full blood-group and secretor testing of populations has hitherto been done almost entirely in a small number of laboratories. Most of these have other responsibilities and cannot, without help, greatly increase their work. Some of them could do more if they were assisted to employ additional staff. It will, however, almost certainly be necessary for other laboratories already doing advanced blood-group testing to undertake some of the work. Financial help may be required, but usually the main need is to enlist the personal interest of the director of the laboratory.

For other blood and urine factors, facilities vary greatly. For some, such as haemoglobin variants, facilities are probably adequate to deal with all the material likely to come in. For others, such as the Gm and InV groups, it is likely that facilities will need to be expanded greatly, either by existing serological and biochemical laboratories adding the testing of these factors to their repertory, or by laboratories already doing these tests on a small scale increasing their capacity. This is likely to need some financial assistance.

(*d*) *Long-term storage of specimens*

It is likely that further blood-group antigens will be discovered and that the present rapid rate of discovery of genetically determined plasma protein types will continue. Blood specimens collected in the near future should ultimately be typed for the new factors; thus it is important that red cells and serum or plasma be preserved in a biologically active form. Biopsy specimens also need to be preserved in a viable condition.

Further research is needed in order to discover the best methods of preservation, but in general red cells are best preserved either in liquid nitrogen or at −70°C with the addition of glycerol. Valuable serum or plasma specimens should be frozen at the lowest available temperature, but for some purposes may be freeze-dried.

The maintenance of the necessary low temperatures without intermission for years is most important. The total volume of specimens is likely, also, to tax severely the storage facilities of most of the laboratories directly involved in the project. It will therefore be necessary to set up cold-storage centres of appropriate capacity and with a very high standard of maintenance expressly for the purposes of the project.

(*e*) *Data-processing centres*

Studies of the type under discussion may involve the collection of hundreds of items of information concerning a single individual. They may also involve the collection of intercorrelated data, such as anthropometric measurements on the state of the hand and wrist ossification centres.

The systematic exploration of relationships between these items, or the derivation of multivariate means and n-dimensional vectors, involves an amount of labour that in the past would have precluded many types of calculation now made possible by the use of high-speed, electronic data-processing machines. Unfortunately, this equipment is not available at many research centres. It is suggested that the possibility be explored of subsidizing a limited number of centres to receive data from qualified investigators and subject them to properly designed programmes of analysis. It should be stressed that careful consideration must be given to the state in which such data should be submitted, and the precise amount and form of analysis to be expected from a centre. Financial provision will be needed for programming and the purchase of computer time.

Attention is also drawn to the fact that for many problems of interest to the population geneticist, no one individual will be able to collect a decisive amount of information. The combination of the results of various investigators, following agreed research designs, will be necessary. Data-processing centres could play a useful role in this regard.

6. TRAINING OF RESEARCH WORKERS

The Group stressed the general shortage of technical personnel for the studies envisaged here, particularly of human geneticists, serologists, social anthropologists and linguists. Moreover, because of the interdisciplinary nature of the research, there is a need to encourage the specialized training of persons with a particular inclination for such studies. This could be achieved by encouraging the exchange of technical personnel between institutions specializing in different but interrelated disciplines. Specific recommendations on this subject are made at the end of the report.

7. RELATIONS OF THE RESEARCH TEAM WITH THE POPULATION STUDIED

Any research team has certain ethical obligations to the population under study. It is essential that harmonious relations be maintained both during and after each research visit. From previous field experience, the following factors have been found to be especially important.

(*a*) The privacy and dignity of the individual must be respected at all times and the anonymity of subjects must be maintained in publications. The comfort and individuality of subjects must be safeguarded, e.g., some people are unwilling to queue, or to have others present during examination or questioning.

(*b*) Satisfactory reward should be provided for the subject's participation in the research and for any services provided. The nature of the recompense should receive careful consideration. The advice of local authorities may be invaluable, both in this and in general so as to avoid giving offence through ignorance of local customs.

(*c*) Provision for medical, dental and related services should be made.

(*d*) The maintenance of congenial social relationships will be enhanced by methods suitable to particular areas, e.g., eating with families on occasion, exchange of information.

(*e*) All groups have learned individuals, e.g., experts on oral traditions and those with systematized knowledge and interpretations of natural phenomena. Consultation and exchange of information with such persons will often be of immediate value to ensure good relations and lead to the appreciation of the achievements of such peoples. Such information is pertinent to their cultural and therefore biological history.

(*f*) There should be the utmost regard for the cultural integrity of every group. All possible measures should be taken to prevent the activities and presence of the research team from adversely influencing the cultural continuity of the population being studied.

8. RECOMMENDATIONS

The Scientific Group recommends that the World Health Organization :

(1) Explore means of starting immediately preliminary studies of the type outlined above on selected groups in each of the regions surveyed in this report. Although preliminary studies may not always lead to pilot and full-scale investigations the possibility of continuity should be given full attention.

(2) Explore the possibility of assisting appropriate groups of specialists to launch pilot studies and of locating financial support for full-scale studies, with adequate planning for continuity.

(3) Bring the possibility of these studies to the attention of the appropriate governments.

(4) Give attention to the provision of assistance to enable the processing and analysing of data, both cultural and biological, to continue after the completion of field studies.

(5) Explore the possibility of collaboration with the International Biological Programme of the International Council of Scientific Unions.

(6) Within its fellowship and training grant programme, provide for :

(*a*) the training of students in the various fields involved in these comprehensive projects ;

(*b*) the exchange of students between different universities and scientific institutions ;

(*c*) the exchange of personnel to provide theoretical and practical instruction in interdisciplinary studies.

(7) Encourage periodic meetings of the various specialists involved in studies in different areas to ensure the exchange of relevant information. It is suggested that one or more mathematicians be invited to these meetings.

(8) With the help of experts, assist in such matters as the standardization of techniques for studying morphological variation, the collection of materials for laboratory study, and the preparation of genealogies for the extraction of genetic information.

(9) Stimulate international collaboration to ensure the adequate supply of rare antisera from the world's blood-group laboratories to enable population genetic studies to be carried out.

(10) Stimulate research on the production of blood-grouping antibodies which are at present in short supply. Encouragement should be given to the development of new techniques for the storage and preservation of the biological activity in blood cells, serum and biopsy material.

(11) Make available to the respective governments and appropriate international organizations concerned, any observations regarding the demographic decline of the populations studied.

(12) Consider the possibility of making material contained in this report widely available.