A BIOLOGICAL APPROACH TO MEDICAL GEOGRAPHY*

BY

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Everyone knows that frost-bite occurs at the North Pole and heat exhaustion is more common in the Tropics. There is a tendency to look upon medical geography as merely an elaboration of this simple theme, but it is not merely a descriptive subject: it is a most fascinating part of human ecology or social biology—the vitally important sphere of human natural history to which geography is an essential background.

The method of approach followed in this paper was indicated by studies of the medical geography of scrub-typhus made in India and Burma during the war and followed up in Malaya (Audy, 1947; Audy and Harrison, 1951). An attempt is made to apply the ideas and methods of the biologist to the problem, with the support of facts gained by recent studies of animal parasites. The main object here is to stress the contribution that can be made by studying assemblages of parasites as a whole; it is therefore concerned almost entirely with diseases caused by organisms.

The term "parasite-pattern" is used here to describe the whole assemblage or array of parasites (including all pathogens) which are associated with a host population being discussed. By extension of this meaning, I also speak of the "pattern" of disease caused by some of the parasites. My object is to relate the parasite-patterns of various communities to those elements of human existence and behaviour which themselves reflect the geographical background in one way or another. To complete the associations I here call the relevant elements of existence and behaviour of a community its "social-pattern."

Patterns of Disease in Somaliland

I will first consider the semi-desert and thorn-scrub of Somaliland. There are great stretches of sparse grassy plains or thorny scrub with widely scattered water-holes. This sort of country must evoke a distinct type of response from the primitive community which first occupies it. It sets a low limit to the overall population, which is almost entirely pastoral and supported by drought-resisting beasts of burden and livestock, such as camels and mules, goats and fat-tailed sheep. The community soon learns that it cannot continue grazing its animals in one place. Not only is it forced to discover and use seasonal grazing areas, but this together with the scarcity of water will also encourage a natural tendency to form well-knit tribes, with tribal grazing areas and some sort of portable villages composed of tents or their equivalent, which can easily be folded up and taken elsewhere. Naturally, the use of such portable huts, which in Somaliland are small hemispherical cocoons of matting, encourages sleeping in a compact huddle. In such ways the geography of the place has a tremendous influence in guiding the pattern of existence of the community or what in this paper is referred to as the social pattern.

Linked to this social pattern in response to a particular and exacting environment is the pattern of disease. Relatively few rural diseases occur in Somaliland, but, as would be expected, there is a pattern related directly to the habitat. Malaria is highly seasonal and highly localized, spreading outwards from small foci during the short rainy season. The general standard of nutrition is low and outbreaks of nutritional disorders occur in bad years. The incidence of desert sores following minor injuries, often leading to severe crippling, is high. In addition to the desert sores, there is a moderate incidence of mycetoma (Madura foot), the fungal spores being inoculated into the skin by the thorns and similar parts of plants on which the fungus concerned appears to grow naturally. Cataract and eye infections are associated with the flying sand and glaring sun, as well as with the flies which thrive in villages. The very free breeding of the flies is directly related to the dry climate. The presence of numbers of soft ticks carrying relapsing fever is also related to the climate. So also is the presence of many herds of animals, including packs of jackals and hyenas, among which rabies is permanently established.

Heavy and regular rainfall has a general cleansing effect which has not yet been properly assessed. Its absence in Somaliland may help to account for much of the spread of intestinal and respiratory infections as well as for the zymotic diseases. The intense dryness and frequent sand-storms encourage sore throats, which the Somalis have been led to treat heroically by snipping off the uvula, usually with slender home-made scalpel and a sharp hook made from an umbrella-rib. Respiratory infections, including tuberculosis, are encouraged by the huddling together in the tiny portable huts, while their effects are made worse by malnutrition.

Malaria in Ceylon

It would be desirable to draw parallel pictures of other places, but these pictures rapidly become much too complicated. I now turn to single diseases in particular places. Malaria offers countless illustrations of medical geography. Ceylon has a particularly fascinating malarial history, culminating in the mastery of epidemic malaria in recent years by a well-planned D.D.T. campaign. The vector mosquito is not very efficient and requires to be present in relatively large numbers for successful transmission. It breeds in clean open pools and puddles, especially in stream and river beds. When these biological requirements are imposed on the geography of the island a very distinctive and peculiar malarial pattern results.

A central mountain-mass breasts the prevailing monsoons and encourages heavy rainfall in the south-west quadrant of the island. Most of the island, however, has a very dry season. Malaria in this "dry zone" is perennial and there is a regular malaria season during the rains. By contrast, the lush, densely populated wet zone in the south-west offers little to the vector mosquito and it is curiously free of malaria in ordinary years. Occasionally during exceptionally dry years certain rivers almost dry up, forming extensive chains of pools in which the vector breeds by the million. This led to violent epidemics in the non-immune population—such as that in 1934–5, when over 80,000 deaths were attributed directly to malaria. Man has aggravated this situation by extensive deforestation in the hills, which results in less retention of water in the catchment areas and tends to produce more rapid changes of water-level in the rivers with more frequent pool-formation during dry spells.

The Typhus Fevers

The next example is the typhus fevers, caused by rickettsiae and transmitted by insects, ticks, and mites. These rickettsiae fall into three groups. The two most primitive groups, carried by ticks and mites, cause infections of small mammals and their parasites, and are only accidentally conveyed to man by a few of these parasites when he loiters in infested places. The vectors are restricted in their distribution in two ways: firstly, on a small scale to patches or "islands" such as a particular stretch of a valley or a single field; and, secondly, on a large scale to geographical regions where conditions are generally favourable for the development of the vectors. Ticks abound in drier tracts outside the rain-forest, so that tick-typhus is practically confined to such country. The mites which carry

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scrub-typhus have their home in south-east Asia, where they now abound in the rat-infested scrub which follows deforestation. Scrub-typhus is confined by what are probably formidable barriers to the further spread to the vector—by tropical deserts, ice deserts, and great mountain ranges on the mainland, by extensive oceans which have almost stopped spread elsewhere, and by excessive dryness which has hindered all spread beyond a very small part of tropical Australia.

An interesting feature of both tick- and scrub-typhus is that the disease shows definite changes in character and severity from place to place. This can be correlated with serological types of the rickettsiae concerned. This is most pronounced with tick-typhus, in which local characters have given rise to a larger number of place-names for different forms.

The third group of rickettsiae is distinctive by having become adapted to life in the guts of insects. Flea-typhus, the more primitive member, is carried by various rat-parasites and transmitted to man by the same rat-fleas as carry plague. Because the domestic rat and its fleas are concerned, flea-typhus is urban and almost cosmopolitan in its distribution. In the most recently evolved member of this group, the flea-borne rickettsia has become adapted to the human body-louse. This at once results in three things: firstly, a restriction to cold climes or high altitudes, and cold seasons; secondly, a tendency to spread from man to man in the form of a swift epidemic; and, thirdly, an extension into regions where the rat-flea has no influence. Although both flea-typhus and epidemic or louse-typhus are essentially urban, the requirements of the vector have shifted the distribution of louse-typhus away from the equatorial belt and far into and beyond what Marston Bates calls the Intemperate Zones.

Parasite-patterns of Animals

These examples have been treated superficially. A deeper study confirms that there are important relations between the entire disease-pattern of a community and its geographical background. Recent investigations in Malaya have given some useful facts with which to approach this problem. Nearly 20,000 animals and their parasites, from forest, scrub, plantations, and towns, have been studied in Malaya since 1947 (Audy and Harrison, 1953). One of several objects of this study was to investigate the parasite-patterns of these animals and to attempt to use the parasites as "ecological labels" (Audy, 1947). The parasites concerned are all those viruses, bacteria, protozoa, fungi, worms, and arthropods which live on or in or at the expense of higher organisms such as the vertebrates, whether harmlessly or harmfully. At a rough estimate there are perhaps 50,000 known species of these parasites potentially able to parasitize the vertebrates, including man. Although very many parasites are available, the whole population of any host in any locality usually supports only a few dozen. The assemblage of these commoner parasites, of various kinds and in varying numbers, constitutes a pattern. I am concerned with the reasons why these patterns differ among themselves in different communities and why they involve but a fraction of the available parasites.

The tree-living squirrels in the Malayan rain-forest support some 30 species of parasitic mites which together make up a pattern broadly characteristic for these squirrels. Ground-rats which live in the same area have quite different parasite-patterns. There is a rat (*Rattus canus*), however, which has a pattern essentially like that of the tree-squirrels and unlike that of the ground-rats. A correct inference from this is that *R. canus* lives in the trees like the squirrels. The picture is completed by the ground-squirrels, whose parasite-pattern is like that of the ground-rats. There is reason to believe that other groups of parasites would give more or less similar contrasting patterns, and would suggest that the parasite-pattern is directly related to the environment, to the conditions of life, and to the way of living of the host.

This supposition is supported by the parasite-patterns found in certain rats. Three of these rats are very important commensals* of man in Malaya. They are either absent from or rare in the native forest but occur in great numbers in conditions created by man following deforestation and settlement. These three rats are the Malayan wood-rat (*Rattus rattus jalorensis*), the field-rat (*R. r. argentiventer*), and the house-rat (*R. r. diardii*). Although all the parasites of these rats are completely interchangeable, each kind of rat supports a distinct assemblage of parasites; each has a parasite-pattern of its own. This is entirely owing to the fact that these particular rats are living in different conditions—the wood-rat in oil-palms, the field-rat in grassland, and the house-rat in towns. In other words, the differences in parasite-patterns are related to small-scale geographical differences. A fourth rat, *R. r. jarak*, comes from an uninhabited island, Jarak, in the Malacca Straits. This rat is virtually an escaped house-rat, introduced long ago to the island and running wild on the forest floor. In the absence of predators and competition, the Jarak rat has overpopulated the island and is unusually heavily infested by worms and other parasites (Audy *et al.*, 1950). However, the parasite-pattern of the Jarak rat is found to be of the same type as that of a typical forest rat, *R. mülleri*.

Geographical Background and Disease-patterns in Man

The example given by these rodents establishes an important point of view. What has been illustrated by rats applies directly to man. Soil and vegetation are decided originally by climate and geology, and the vegetation and climate together decide the structure of the animal communities that will be found. If man appears on the scene, the climate, vegetation, and soil, and to a varying extent also the animal life, play a great part in deciding for him how his social pattern is to develop; how he will grow or hunt his food; how much clothing he will wear; what sort of shelter or house he will build; whether or not he will be subject to catastrophes such as floods or erosion or drought or the choking up of his clearings by intractable weeds; and whether or not he will wander about or remain to form either compact or scattered settlements. As his social pattern develops, his pattern of parasitism becomes established, and in these early stages the whole complex is related to the geographical background.

Man immediately starts altering the geographical background—for example, by widely destroying the vegetation. So his social-pattern and his pattern of diseases gradually change, but, even so, they are related to the environment. The change is largely one of emphasis.

The disease-patterns are, of course, greatly modified by various purely human social elements. Religious taboos relating to food affect the incidence of tapeworm; religious fasting may add to the effects of undernourishment. Schistosomiasis in the Yemen is almost confined to the ritual ablution pools in mosques (Kuntz, 1952). Social elements have a tremendous influence on the pattern of expression of all the treponematoses. The "civilization" of many communities, or the introduction to them of many outsiders with a higher standard of living, may unmask infections which have hitherto saturated the communities and kept up a general standard of immunity dating from childhood. Poliomyelitis and the viral encephalitides are important examples; in certain circumstances malaria is another example. Finally, a peculiarly human element is introduced by urbanization.

In due course there is always more or less urbanization of the community, and at the same time more frequent and wider traffic with other places. Many diseases, especially epidemic diseases, appear by introduction from areas which may be remote, to be added to a distinct urban pattern of disease. Traffic between urban centres leads to a dispersal

*Commensals include organisms and creatures that "parasitize" the nests of hosts or other parts of the environment which the hosts have characteristically modified, rather than the bodies of individual hosts.

of diseases and a tendency for urban patterns to be similar over very wide areas. Many urban epidemics tend to involve the rural population secondarily. Finally, there may be industrialization, which evokes its own elements in the disease-patterns. These industrial diseases are, like the rural diseases, often very closely related to the geographical background: an example is the pneumoconioses, which are related to the geology.

Conclusion

In developing our approach, the attention to assemblages rather than to individual parasites or diseases is very important—it would be described by the biologists as a synecological approach, concerned with the functional setting of organisms in relation to the other organisms, as opposed to an autecological approach, concerned with a single organism and its relations with the environment. Several workers have drawn attention to the pathology of social groups in their entirety. Ryle (1948) approached social pathology with the experience of a clinician: he rightly looked upon society as an organism which may be approached as such by the clinician as well as by the pathologist, the epidemiologist, and the psychiatrist.

Those who are sympathetic towards the philosophy of holism expounded by General Smuts (1936) will at once see that the synecological approach is also holistic. The lesson is that as soon as components have been sufficiently studied in isolation, they should then be set provisionally into their organized system or pattern and that the system should be studied as an organism in its entirety. Taking the analogous parasite-patterns of rodents, we have been enabled, from anomalies appearing in the patterns, to make inferences and plan investigations which would not otherwise have occurred to us. These anomalies could be detected only by studying the patterns as patterns and not by studying isolated parasites.

Summary

The whole assemblage of diseases from which a community suffers forms a pattern which can profitably be viewed as a whole. Those diseases caused by organisms form part of a general parasite-pattern. With examples of such patterns drawn from studies of rodents in Malaya, the parasite-patterns are considered to be decided largely by environment—that is, by the geographical background (which may be taken on a very small scale).

The distribution of diseases in different communities in different places is approached by a holistic study of the relationship borne by the entire disease-patterns of the communities to the social patterns and the geographical background. As a simple example, it is suggested that the disease-pattern in Somaliland is more or less evoked by the geography of the country. Further illustrations are drawn from malaria in Ceylon and from the typhus fevers.

In the earliest stages of man's occupation the link between geography and the disease-pattern appears to be very close. Man soon alters his environment, but the disease-patterns, while changing also, are still related broadly to the environment, and the change is largely one of emphasis. Urbanization, however, evokes urban patterns of disease, which tend to be widely distributed and uniform in nature, largely by interchange between urban environments, which are essentially the same everywhere. Industrialization evokes new elements, which again may become closely linked to the geographical background.

The methods and aims of medical geography, or medical ecology, are of interest even to those concerned with preventive medicine in the most urbanized or stereotyped environments. A particular biological approach is here added to those which are already familiar.

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HAEMOLYTIC DISEASE OF THE NEWBORN CAUSED BY A NEW Rh ANTIBODY, ANTI-C^x

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Haemolytic disease of the newborn commonly occurs in Rh-negative women who are delivered of Rh-positive children, where the mother has Rh antibodies in her serum. Cases are also seen in which Rh-positive mothers are delivered of children affected with this disease; in the majority of such cases the maternal serum contains Rh antibodies anti-E or anti-c. Antibodies to other blood-group antigens—for example, anti-Kell—may also be present in the maternal serum and give rise to this condition. Occasionally, haemolytic disease of the newborn is caused by antibodies to much rarer blood-group antigens; these may belong to the Rh series—for example, C^w—but a number of cases have been described in which the cause has been a family antigen.

The family antigens appear to be of two kinds—those which have been observed because they have given rise to haemolytic disease of the newborn, and those which have been found within a family but are not associated with the occurrence of this disease. Those which have caused haemolytic disease of the newborn have been described by Levine *et al.* (1951) (Miltenberger); by Holman (1953) (Wright); and by Davidsohn *et al.* (1953) (Berrens). These blood groups are confined to the members of the family in which the case of haemolytic disease of the newborn occurred.

The present case occurred in a third pregnancy, and was originally thought to be due to a family antigen, but subsequent investigations suggested that it was, in fact, a rare Rh agglutinogen at the C-c locus, C^x. It is proposed in this paper to describe the clinical history of the case and certain serological findings, and to discuss their importance. Detailed serological work and family studies will be described in full elsewhere.

Clinical History

The mother had had two previous pregnancies: in 1947 a full-term normal male child, who is alive and well; and in 1950 a 7-months pregnancy resulting in a stillbirth.

In 1953 a full-term male child, weighing 8 lb. 2 oz. (3.7 kg.), was delivered normally. The child was jaundiced at birth, but this had faded by the third day. He was artificially fed and gained weight normally. He vomited twice during the first week of life, and on the tenth day was noticeably