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Widening Horizons

The world-wide truth that new times demand new measures is demonstrated in many phases of geographical research, most particularly, perhaps, in the broadened concept of the geographer’s increasingly responsible role in the promotion of human welfare, secondarily in the development of new techniques of investigation. The Society’s program of studies in medical geography, initiated in 1944 and formulated under the direction of Dr. Jacques M. May in 1948, is an excellent case in point, as will be evident from the present article on methods and objectives and from future reports on specific projects.

Dr. May combines a deep interest in the problems of man versus environment with a wide experience as a practicing surgeon on four continents. During his eight years in the Asiatic tropics, first as chief surgeon of the French hospital in Bangkok and later as professor of surgery at the Medical College of Hanoi, Dr. May accumulated a wealth of experience, which later formed the basis for a book, published in 1949. “Siam Doctor” is at once a collection of colorful episodes gleaned from a career rich in incident and a stark record of the difficulties inherent in tropical medical practice—barriers of language and custom, lack of sanitation, deficient diet, and, above all, the voracious physical environment. It is to be hoped that two projected sequels, “African Doctor,” based on Dr. May’s service as a surgeon with the Free French forces in Africa during the war, and “Caribbean Doctor,” recording his adventures as chief surgeon of Guadeloupe, in the French West Indies, will be forthcoming.

New horizons have also appeared in the realm of political geography with the change in status of several hitherto dependent areas. Ceylon, which achieved Dominion rank in February, 1948, “not by force or unconstitutional agitation but by persuasion,” entered upon its career of independence faced with critical problems (Pacific Affairs, March, 1949). However, a hopeful aspect is the procurement by the Ceylon government of the services of numerous expert advisers—engineers, sociologists, medical specialists, industrialists, and so on (Crown Colonist, November, 1949)—with the recognition that “undertakings planned without such aid have turned out to be failures.”

The island’s economy has long been based on the products of plantation agriculture and therefore has been subject to the vagaries of world markets; the obverse of the coin was the necessity for importing a large proportion of the food supply, generally as much as two-thirds. B. H. Farmer’s survey
MEDICAL GEOGRAPHY:
ITS METHODS AND OBJECTIVES*

JACQUES M. MAY

WHAT is “medical geography”? What is the substance behind the two words? Is there any substance at all? Is there anything that has not been studied in one of the accepted classic specialties, such as epidemiology or parasitology? This article is an attempt to explain what is meant by the term “medical geography” or the expression “geography of disease.” It fully confirms the notion that there is nothing in medical geography which is not based on well-known facts widely scattered through the various branches of medicine. What may be new is the approach to the problems raised by the definition—not the idea that such an approach should be made, since this was understood by Hippocrates—and the method by which the approach can lead us on solid earth from the clouds of imagination. The accompanying tabulation (p. 36) is a tentative suggestion as to the specific points that might be investigated.

For many years the attention of physicians has been focused on the symptoms of disease. More recently, with progress in chemistry and physics, attention has been given to the biochemical disorders that are the result of disease. The approach has deepened and explores below the surface. Today we recognize that disease is a multiple phenomenon which occurs only if various factors coincide in time and in space. The focus of interest widens to encompass the relationship between the various factors of this complex and their respective geographical environments. This can be called “medical geography.”

THE ELEMENTS OF MEDICAL GEOGRAPHY

What pathological factors enter into the composition of a pathological complex? What geographical factors determine its evolution and behavior?

Medical geography is the study of the relationships between them—the pathological factors, which have been called “pathogens,” and the geographical factors, which we propose to call “geogens,” and possibly others not listed

*The program of studies in medical geography was financed (1948–1949) by a grant of $15,000 from the Upjohn Company.

Dr. May, head of the Society’s Department of Medical Geography, was formerly professor of surgery at the Medical College of the University of Hanoi, French Indochina. His studies of the human response to surgery there and in Siam, Central Africa, and the Caribbean, where he has also worked, led to his present interest in medical geography.
here. Some of these relationships are well known; many have not yet been
explored in a sufficient number of cases to have statistical significance. Let
us review certain of these factors, mentioning some of the known correla-
tions as we go.

**Pathological factors**


**Geographical factors**

1. Physical
   - Climate
   - Latitude
   - Rainfall and humidity
   - Temperature
   - Barometric pressure
   - Sunshine and cloudiness
   - Wind direction and velocity
   - Radiation
   - Static electricity
   - Ionization
   - Relief
   - Soils
   - Hydrography
   - Terrestrial magnetism

2. Human or social
   - Population distribution and density
   - Standard of living
   - Housing
   - Diet
   - Clothing
   - Sanitation
   - Income
   - Communications
   - Religious customs and superstitions
   - Drug addictions

3. Biological
   - Vegetable life
   - Animal life, on earth and in water
   - Parasitism, human and animal
   - Prevalent diseases
   - Dominant blood groups

Disease is related to the physical environment in numerous ways, of
which we shall study only the two principal ones: when it occurs as a result
of parasitic infection; and when it occurs as a result of the nature of the
water and food ingested. We shall follow up this study with a few specific
examples.

**DISEASE AS A RESULT OF PARASITIC INFECTION**

Animal and plant life multiplies, often using man as its environment and
growth medium; a resulting disease is nothing more or less than the human
view of the phenomena that ensue. If we can escape from our understandable
anthropomorphic bias, such diseases can be recognized as merely the by-
product of an accidental collision between two or more forms of life, each
pursuing its own destiny.

**Pathological Factors**

1. *Causative agents* are those whose presence actually causes the disease.
   Their nature is still very much under discussion. Many of them are too small
to be seen with a microscope; others can be seen under a microscope but
not with the naked eye; still others can be seen with the naked eye. They

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1 D. G. of Virus Aer pp. 11-15; C Lansing) à l’É
3 S. Gar d’Hygiène Pub
are provisionally classified as viruses, rickettsias, spirochetes, bacteria, fungi, protozoa, and metazoas.

Viruses are minute pathogenic organisms exhibiting the highest known degree of parasitism—they cannot exist outside living cells, whereas bacteria, for example, can be cultivated on laboratory media. The size of the viruses ranges from 8 millimicrons (foot-and-mouth disease) to 230 millimicrons (psittacosis). Viruses pass through ordinary fine bacteriological filters; their mode of reproduction is still unknown.

A definite correlation seems to exist between a number of these viruses and temperature, humidity, electrical and magnetic fields, and ultraviolet radiation. The geographical distribution of foot-and-mouth disease in the United States and Mexico and in some Central European countries might be explained by correlation with a yet unidentified geographical factor, as might the periodicity of measles and various other viral diseases. It has been shown that low temperatures delay the onset of epidemics of sand-fly fever in India, whereas early warm weather usually accelerates outbreaks. Of course, since studies are incomplete, other factors may explain periodicity, such as the rise or fall in the number of susceptibles; but there is a strong possibility that certain local geographical factors are favorable for the growth or multiplication of a virus in the living cell in which it exists. The geographical or locational factor is, indeed, one of the few facts known about some diseases and is reflected in the name given to the disease—for example, Bunyamwera fever, Wumba fever, Semliki Forest fever, Colorado tick fever.

Polioyelitis seems to be correlated with the seasons, since outbreaks always occur in summer and fall, in both the Northern and the Southern Hemispheres. Gard found that an epidemic of poliomyelitis ceases when the temperature drops to 0°C and flares up again when it rises. The epidemics seem to occur in successive small waves, the peak of which is usually preceded by an increase in rainfall. Whether these climatic factors influence the virus directly or favor its passage from one host to another, thus increasing its virulence, is not yet known.

Pioneer workers in yellow fever noted that a spell of cold weather might

affect the course of an epidemic, though this might act upon the vector as well as upon the virus; recent experiments by Bates and Roca-Garcia\(^4\) show that exposure to high temperatures may hasten the multiplication of the virus of jungle yellow fever in the mosquito *Haemagogus capricorni*. Similar results have been found when the virus is studied in *Aedes aegypti*.

Rickettsias are living organisms slightly larger than viruses and, like them, are completely parasitic and cannot exist outside living cells. Rickettsias are usually found in arthropods and are highly adapted to their hosts. They can be differentiated into three important geographical groups. The Rocky Mountain spotted fever group, linked with ticks, is found chiefly in North America and Brazil, and possibly on the Mediterranean coast of North Africa and the Atlantic coast of South Africa; the Asiatic group, closely linked with mite-borne infections, is found in Japan, South Asia, Formosa, and Oceania, where it causes the tsutsugamushi disease, or scrub typhus; a third group, more widespread, is found chiefly in Europe and Central Asia and is linked with fleas and lice, the former causing endemic, and the latter epidemic, typhus.

“Spirochetes” is the name given to living organisms classified sometimes as bacteria, sometimes as protozoa. They are found throughout the world, but certain species seem to have definite geographical associations. Some live in the blood of man and are transmitted by the bite of lice or ticks. These are common in Europe, Asia, and Africa and have been found in the United States. There seems to be considerable evidence that the species in the Old World and the New are biologically different. Nicolle and Anderson feel that these blood spirochetes of man were originally parasites of small burrowing mammals. This seems to be confirmed by the fact that wild rodents commonly serve as animal reservoirs, especially in California.

Another group passes directly from rodents to man, when man ingests food or water contaminated with the urine of an infected animal (infectious jaundice). A third group needs the bite of the rat to introduce the spirochete into human blood, causing a disease called “rattibe fever.” Other spirochetes normally inhabit the tissues of man, causing syphilis, which is widespread, or yaws, which is limited to certain tropical regions, or bejel, localized in the Euphrates Valley, or *mal del pinto*, localized in South and Central America. In all of these transmission seems to be direct, without the help of an obligate vector, though in yaws the fly may help. The factors that


produce such close correlation of each.

Bacteria human disease: disease in nature geography, serving of spread form. are few, limited to the factors that are disease of the world which was Europe and is caused by several rodents. In this, as in the endemism of the Indies, and habitation spread passage from one to another.

Fungi are morphological: which branch mycelium or budding governed by the situation that makes for a number.

Protozoa: most widespread: *plasmodium* in South America of these parasites such as the
produce such a different geographical distribution of organisms biologically so closely related could perhaps be found in the study of the environment of each.

Bacteria are a vegetable group comprising a large number of agents of human disease, most of them widespread throughout the world, causing disease in endemic or epidemic form. From the point of view of medical geography, the endemic aspect is the more interesting and the more deserving of study. Cholera has been observed all over the world in an epidemic form. But endemic foci of cholera from which epidemics spread out are few, limited to certain spots in India and possibly in China. What are the factors that transform endemicity into epidemicity? Similarly, tularemia, a disease of rodents caused by Pasteurella tularensis and communicable to man, which was first described in the United States, has been observed also in Europe and Siberia. The causative agent has its propagation in nature assured by a large variety of ticks in all stages of their development. Several rodents harbor the infection; man breaks into the cycle accidentally. In this, as in many other cases, the enzootic largely trespasses on the limits of the endemic. Melioidosis, a disease caused by Actinobacillus pseudomallei, has been observed only in Malaya, Indochina, Ceylon, the Netherlands Indies, and China. The factors that confine these bacteria to their present habitation should also be investigated. Many of the factors that govern the passage from endemicity to epidemicity and vice versa are still a mystery.

Fungi are a group of plants related to bacteria, but larger. They are morphologically characterized by the filaments (hyphae) they produce, which branch and intertwine to form a "dense mat of growth," the mycelium. They may be multicellular and may multiply either by fission or budding or by means of asexual or sexual spores. Their existence is governed by various factors, such as humidity and temperature, a correlation that may explain their geographical distribution. They are responsible for a number of pathological conditions.

Protozoa are a large group of unicellular animals that cause some of the most widespread tropical diseases, such as malaria (whose causative agent, a plasmodium, is dependent on both man and mosquito for its existence), South American and African trypanosomiasis, and amoebic dysentery. Some of these parasites live independently and may encyst for protection. Others, such as the Trypanosomidae, are probably insect parasites primarily, some of

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which can be transferred from one animal to another, including man, by flies. Metazoa are more complicated. They grow to be visible to the naked eye and comprise all the helminths that inhabit the tissues (type: trichina) the bowels (ascarides, hookworms), the circulatory system (schistosomes, filariae), and the viscera (liver flukes, etc.) of man. The life of these animals is conspicuously related to the environment. Their eggs need certain soil conditions to hatch; their larvae require certain intermediate hosts to develop and certain vectors and circumstances to reach their permanent hosts. In all these stages they are subject to powerful geographical influences. For example, *Schistosoma haematobium* is a worm that normally lives and lays eggs in the veins of the bladder of man. When mature, the eggs are expelled through the mucosa of the bladder into the urine, and as soon as they reach a suitable medium they hatch. The miracidium escapes into water and swims freely until it encounters the appropriate intermediate host, a snail, in which it develops. This must happen within 16 to 32 hours. After a period of four to eight weeks, a fork-tailed cercaria breaks out of the snail and swims freely in the water until it reaches the skin of a man, where it attaches itself and bores its way forcibly through the skin, casting off its tail. After two or three months of migration through the various human tissues and viscera, it reaches the adult sexual differentiated stage in the veins of the bladder, and the cycle is complete.

2. *Vectors.* The causative agents reach man in various ways, directly or indirectly. Some attack through the respiratory passages; for example, the viruses of measles, mumps, smallpox, and the respiratory diseases. Others are swallowed with food, as in cholera, typhoid fever, amoebic dysentery. Still others bore through the skin, as in ancylostomiasis and schistosomiasis. Numerous diseases, however, are introduced into the human system only through the action of a vector. Most vectors are arthropods. They may transmit the germ superficially, as in the case of flies, cockroaches, and beetles that pollute human food or skin with their feet, saliva, or feces; or internally, as in the bite of lice, ticks, mites, and mosquitoes.

Understandably, the life and activity of these vectors are inescapably bound up with factors of the geographical environment. *Glossina palpalis,* for instance, the most important vector of African sleeping sickness, requires a relatively dense wood or thicket of a more or less evergreen type, and the larvae need a certain kind of sand in which to develop. The many species

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of anopheline mosquitoes require various breeding habitats. *Anopheles crucians* breeds in both fresh and saline water; *A. barbiro* prefers the water that remains in tree holes; *A. bellator*, common in Trinidad, breeds atop bromeliads; *A. gambiae* breeds preferably in unvegetated, sunlit, shallow pools. It should be noted, also, that certain species of mosquito are vectors in some places and not in others, though the reasons for this are not yet clear. For example, *A. hyrcanus* carries malaria in China, Malaya, and the East Indies but has not been found to be infected in India.

Malarial mosquitoes have various habits of life and flight, and their peculiarities influence the overall complex. Some mosquitoes bite at dusk, others at dawn; some penetrate into the house, others never come indoors; some prefer animal blood, others discriminate between white and colored human beings. There seems to be evidence that biting habits are related to the sexual cycle, and breeding habits to the type of soil. However, all species can adapt themselves to a new type of surface soil, so that infinite possibilities exist for change in the complex at any given spot. Flying range depends partly on individual characteristics, but wind direction and velocity, humidity, and temperature are important influences on the behavior of the mosquito and therefore have a direct bearing on the epidemiology of malaria.

3. **Intermediate hosts.** A third factor that may enter into the pathological complex is the intermediate host, an organism essential to the life cycle of the agent. These intermediate hosts are commonly recruited among mollusks (human fluke infections), fish (*Diphyllobothrium latum*, broad tapeworm), and mammals, such as man in hydatid disease.

4. **Reservoirs.** The fourth element to be brought into the pathological picture is the reservoir. Such hosts serve to carry the infection in nature, when man is unavailable or suitably protected, and also as a supplement to man. The agent spends part of his life cycle in this host, until he is picked up by the vector or, sometimes, expelled by the host.

5. **Man.** Last of the independent elements that enter into the pathological complex is man, who can therefore also be termed a “pathogen.”

**Geographical Factors**

The various geographical factors should now be correlated individually with every one of the pathogens just reviewed—some factors may be relevant and some may not. The possible results are condensed in the accompanying tabulation. As space does not permit the description of every one of the correlations in the present article—this being the subject and pattern for a whole book—we have selected a few of the geogens, namely
climate, water, soil, and cultural habits, and studied their correlations with the pathogen man.

**CLIMATE**

The influence of climate on man is obvious, but the precise correlations have been only superficially studied. It should be borne in mind, too, that the various elements of climate influence one another; temperature has an effect on evaporation and humidity, for instance, and winds affect temperature. Therefore, when some physiological change is observed in one of the elements of the pathological complex, it may be important to find out whether the change is related to temperature, or humidity, or some other factor. Most of the bodily changes brought about in man by climatic factors are promptly adjusted by the normal play of physiology, and thus only a temporary disturbance is created. The sum total of such adjustments is acclimatization.

Dr. Douglas H. K. Lee\(^\text{3}\) analyzes the scientific study of the influence of climate on man as follows:

"For the first quarter of this century considerations of climatic effect had necessarily to follow one or both of two indirect approaches to the problem. These may be termed the 'survey' method and the 'correlation' method. In the former, more or less systematic examinations were made of persons living under certain environmental conditions, and the results were compared with those obtained by similar examinations of a 'control' population, living under a familiar temperate or 'normal' climate. The difficulties of conducting such surveys on a scientific basis were great, first because there was little information to indicate what types of observation should be made; secondly, because the personnel necessary for an adequate survey were seldom available; and thirdly, because it was difficult to distinguish between the effects of climate per se and concomitant disturbances wrought through infectious disease, malnutrition, economic status, social incentive, and so on. The observation made in this way which most closely met scientific requirements was that of 'basal' metabolism.\(^\text{4}\) This has been meas-

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\(^{1}\) Personal communication to the writer, October 21, 1949. Some further illustrations of climateman relations are found in "Clothing for Global Man" by D. H. K. Lee and Hoyt Lemos (Geogr. Rev., Vol. 39, 1949, pp. 181–213).


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\(^{4}\) E. M. als voorspeld Krogh Metho kundig Tijdschr

\(^{5}\) R. G. 1 Groups: Part Vol. 4 (N.S.) Groups: Part Influence of Europeans, Jo

\(^{6}\) MacGi
ured on a large number of different groups, and its relationship to climatic factors examined."

In this connection we may cite also the work of Mason and Benedict⁹ in India, Streef and Karmawan¹⁰ in the East Indies, MacGregor and Loh¹¹ in Malaya, and others. In Singapore comparative studies were made of different racial groups living under the same climatic conditions. Europeans, Javanese, and Sikhs showed a basal metabolism rate 5 per cent below normal; Chinese, Malays, Punjabis, and Tamils a rate 10 per cent below normal.¹²

Dr. Lee continues: "Unfortunately, the circumstances of measurement, which should be constant for truly comparative studies, are themselves changed by variations in climate, so that the conclusions are open to some doubt.

"The second approach, correlation, is typically the comparison of the variation in some population feature with that of some climatic index (for example, death rate x mean annual temperature). Provided the data are thoroughly reliable and every effort is taken to see that no bias creeps into their selection or use, this method can provide useful evidence. Unfortunately, it is difficult, even now, to get statistical data that are really comparable as regards either content or reliability over large areas. Moreover, it is a human trait to see those groupings that support a conclusion but to regard as unimportant those that do not fit in with an idea. Statisticians are acutely aware of the ease with which significant differences can be read into comparative data where, in fact, no significance exists. Again, the existence of a difference between two sets of data says nothing about the cause of the difference, and in the explanation of differences it is extremely easy to be swayed by preconceptions. Taking the broad view, this type of study must be treated with a good deal of reserve, especially since the reader is seldom in a position to check the argument for himself.

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¹⁰ G. M. Streef and R. Karmawan: Basal metabolism in de tropen, zoowel bepaald volgens Krogh als voorspeld uit polsfrequentie en polsdruk [Basal Metabolism in the Tropics as Calculated by the Krogh Method and as Determined from Pulse Rate and Pressure (Read-Barnett Formulas)], Geneeskundig Tijdschr. voor Nederlandsch-Indië, Vol. 82, 1942, pp. 72-85.
"The well-known writings of Huntington\textsuperscript{13} date from this period and are based on these methods. They offer many suggestions and stimulate further inquiry, but we must await the production of evidence from the experimental investigators before awarding any final judgment in the matter. The newer experimental approach is essentially threefold: (1) to analyze the practical problem, as it arises in the field, into its component operative parts; (2) to examine each component experimentally under standardized conditions, asking questions, as far as possible, about the effect of one variable at a time; (3) to use the answers and guides obtained by this analysis for a re-examination of the problem in the field. By a repeated turning from the natural, but complicated, problem to an experimental, but somewhat unnatural, study and back again, the real truth is gradually revealed."

Among the climatic factors that have been explored in relation to human health, the most important are heat, light, and humidity. The adjustment of mammals and birds to changes in temperature depends on their temperature regulatory system, which in turn is influenced by many other factors. If this system does not work, overheating and irreversible alterations of the protoplasm occur. In order to combat high external temperature by the loss of as much heat as possible, a peripheral vasodilation takes place, which increases the blood volume at the surface. It looks as though fluids were drawn from the interstitial spaces and transferred into the plasma to increase the dilution of the blood. In the tropics this "wetter" economy\textsuperscript{14} results in a slight tachycardia, expressing the increased work of the heart in pumping a greater quantity of fluid. There is also a transfer of red cells from the deeply seated organs to the surface, which causes a certain degree of anoxia of these organs. The anoxia may or may not be compensated, and it is quite possible that in addition to other causes of anemia, which are numerous in warm countries, there may exist a permanent malnutrition of the most important organs.

That arctic climates will kill an unprotected person is obvious; but, again, physiological evidence suggests that, given adequate thermal protection, man may suffer little physiological change in such climates, though major psychological adjustments may be necessary.

Dr. Lee also points out that questions of the suitability of different races


to particular climates should likewise be subject to the reservations made above. "Ingenious arguments have been put forward to 'explain' the advantages conferred on dark-skinned races by their pigmentation. Experimentalists, however, are doubtful whether any advantage is conferred, or whether pigmentation has any great significance at all for adaptation."

Freer asserts that the skin of Malayans has 12 to 15 per cent more sweat glands than the skin of Europeans. Homma states that in certain parts of the body sweat glands are three times as numerous in the negro as in the white. Loewenthal asserts that the superficial circulation is more extensively developed in the black than in the white. The thickness of the skin is also different.

At present we know little about regional or racial differences in electrolytes in the blood. Robinson has found that the sweat of a negro has a lower concentration of sodium chloride than that of a white. The metabolism of potassium seems to be related to the deposition of glycogen in the liver and to the level of calcium in the blood, a high blood calcium being associated with a low blood potassium. Natives of Kenya have a low calcium level; Annamites have a high calcium level, which frequently results in urinary lithiasis. Such variations in the concentration of important electrolytes in the blood could be related, among other things, to food, and through this link to the chemical conditions of the soil; but other factors, such as parasitism, probably play a role. Severe mineral deficiencies may cause disease by themselves (rickets) or may favor the onslaught of germs and thus create a pathological condition.

Regions of scanty sunlight produce diseases that are seldom encountered in tropical countries. Rickets, for example, is common in northern industrial regions where winters are long, but it is rarely found in the tropics, though the diet is poor. Of course, sunshine is not the only factor; an adequate amount of calcium should be provided by the soil if rickets is to be avoided. This mineral is found in certain foodstuffs such as milk and green vegetables and in water. It is interesting to note that the city of Glasgow, one of the

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18 S. Robinson and others: Adaptation of White Men and Negroes to Prolonged Work in Humid Heat, Amer. Jour. of Tropical Medicine, Vol. 21, 1941, pp. 261-287.
greatest centers of rickets in Europe, is supplied with unusually soft water from Loch Katrine. The mechanism by which rickets occurs through lack of sunlight is now well understood, but other factors probably exist.

WATER

Water is collected in many ways, from holes and scrapes in the ground dug out by the bare hands of thirsty nomadic tribes to the elaborate waterworks of civilized cities. Each type of water supply has its special danger.

Water may be contaminated directly, for example by night soil that carries Entamoeba histolytica, Vibrio cholerae, or Salmonella typhosa, or indirectly, as by the laundering of clothes near the margins of wells and streams. It may also harbor intermediate hosts for various flukes. In India and in some other countries where cremation is practiced, the charred remains are placed in rivers. Such customs as this and drinking from consecrated streams result in cholera and other enteric infections. The distribution of step wells as sources of drinking water probably coincides closely with the distribution of dracunculiasis. In India and Uganda the water from step wells and ponds abounds in cyclops, which are the intermediate hosts of Dracunculus medinensis.

Water that has been treated may become polluted in pipes. In the West Indies the frequent earthquakes are likely to shatter the water distribution system and disrupt the connections, with the result that the polluted soil can infiltrate into hitherto unpolluted water. In Guadeloupe, for instance, a liter of piped water has been found to contain as much as four milligrams of fecal matter. In places where the piped supply is not continuous throughout the day, pollution may enter the empty pipes, to be distributed later to the consumer.

The type of irrigation governs the type of schistosomiasis. In southern Egypt the basin system is prevalent. The land is irrigated once a year. The intermediate host of S. haematobium is Bulinus truncatus, which is not common under these conditions, and the disease is therefore rare. In the delta of the Nile, however, where perennial irrigation is practiced, B. truncatus is common and S. haematobium prevalent. On the other hand, S. mansoni uses Planorbis boissyi as an intermediate host. This snail survives only in permanently quiet water. Consequently, S. mansoni is common in the central part of the delta and nonexistent in Upper Egypt. Moreover, B. truncatus and

P. boissyi require water plants on which to attach themselves. They do not live in canals devoid of vegetation.

SOIL

The use of human fertilizer to promote the cultivation of edible plants is possibly one of the greatest single causes of disease in the world. The "fecal peril," as some have called it, covers four-fifths of the inhabited surface of the earth. In North China the excreta freeze on the surface during the winter and are washed out with the thaw; the eggs of many worms and cysts and spores of countless other organisms are spread over the fields.

In India, as in China, bucket latrines are used, and the night soil is collected by untouchables. They dump it into sewers or storage basins, from which it is taken to be used as fertilizer. Finally, promiscuous defecation on the banks of streams, ponds, and rivers leads to widespread pollution and at the same time provides excellent breeding conditions for flies and rodents.

The nature of the soil is also an important factor in the promotion of the life cycle of human parasites. The eggs of Ancylostoma duodenale, for example, do not develop well when the soil is dry or contains much chloride. Such is the case in many Egyptian villages. On the banks of the Nile, however, moisture and temperature are satisfactory for the development of A. duodenale, and therefore inhabitants of riverbank villages are more frequently infected than inland dwellers. Throughout Egypt this condition is such that the rate of infection averages 50 per cent of the total population of the country, ranging (1939) from 15 per cent in Faiyum Province to 90 per cent in Maasara.21

Conversely, the type of soil that favors the development of the eggs of A. duodenale is hostile to Ascaris lumbricoides. Hence an inverse proportion of infestation by both worms in males and females is usually found in Egypt, where men work in the fields and women stay around the home. In Italy, however, the women work in the fields and the men go into the towns to market the produce; hence women bear the brunt of hookworm infestation and men get the ascarides. Cultural factors, such as less soil pollution and the

wearing of shoes (in the case of *A. duodenale*), may change the picture. On the other hand, infection of the soil may be increased if an unabsorptive subsoil makes the drainage system inadequate.

What grows from the soil also has an influence on human disease. Certain plants have allergy-producing pollens; this is a world-wide phenomenon. People can be allergic to the flower of the sugar cane or of the rice plant as easily as to ragweed or timothy. Among the well-known allergies are the various dermatitides, caused mostly by plants of the genus *Rhus*. Allergies are also produced by animals, and allergic phenomena play a part in the symptomatology of the various filariases and of intestinal worms, especially the ubiquitous ascaris.

What lives on the soil has an influence on human sickness. Animal life is, of course, also primarily related to the health of man. The diseases of cattle (tuberculosis), the diseases of rats (plague and ricketsias), the diseases of dogs, cats, and other domestic animals (hydatid disease), and the variety of intestinal worms—each of these is linked with the soil and has its geographical distribution.

**CULTURE**

Man is also tied pathologically to his culture. Foremost among the cultural factors are those related to religion. The common bowls for washing hands in Buddhist temples spread eye, skin, and other diseases. The daily ablutions of Moslem rites are usually performed with polluted water and contribute to its further pollution. Food tabus, too, have an important bearing on health. Buddhists will not eat the flesh of animals. As we shall see, vegetarian diets, tolerable for the rich, who can compensate their lack of animal protein with milk, eggs, and butter, are disastrous for the poor, among whom malnutrition results. Moslems eat mutton and beef but will not eat pork; thus they are susceptible to tapeworms but protected from trichinosis. Religious pilgrimages have paved the way for many an epidemic; the story of the spread of cholera through the pilgrimages of the faithful is well known.

In the Gilbert Islands superstition compels the inhabitants to deposit their excreta in the sea. This habit results in a certain degree of hygiene and prevents the spread of hookworm. But the sea water is used for its salt; added to the food after cooking, it spreads enteric diseases.

Man's housing also contributes to disease or health. In certain countries the houses are raised above the ground and offer plenty of space for rats, mice, and, in some regions, snakes. In Egypt the roofs of many houses have pigeon cotes, which swarm with rats; plague appears more frequently in homes in bankment found hel the first embankn refuge in in the fie houses, th

Japan against th disorders kept cle Padde in the m epidemic Local Sparganc tracted b vertebr Asia. It pigeons applied it frequent with cov it reaches is found consume choice d clothing, the soil c

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homes in which pigeons are kept than in others. Uncemented stone embankments also attract rats; covering the embankments with mortar has been found helpful in combating plague. When plague strikes in a community, the first cases appear in the vicinity of rivers and basins. The rats flee the embankments in August and September to escape the floods. They take refuge in outlying houses or find shelter in heaps of cotton and maize left in the fields; when the maize is brought in to be dried on the roofs of the houses, the rats follow—and so does the plague.

Japanese houses, generally built of light material, afford little protection against the cold. This explains to a certain extent the prevalence of respiratory disorders in Japan. In winter the floors are covered with mats, which, unless kept clean, are a good shelter for fleas.

Padded clothes such as those worn in the cold desert of North China or in the mountains favor lice infestation; the high incidence of louse-borne epidemic typhus in these areas is noticeable.

Local medicines and medical practices have an influence on disease. Sparganosis, a disease caused by the larvae of cestode worms, may be contracted by the application of poultices made of fresh-killed frogs or other vertebrates, as in Tonkin. Such a practice is not, however, confined to Asia. It is still followed in the Mediterranean basin, where fresh-killed pigeons or chickens are believed to cure headache and meningitis when applied immediately to the scalp of the ailing. Tetanus of the newborn is frequent in countries where native midwives dress the cord of the infant with cow dung. Geophagy is common all over Africa. In southern Tunisia it reaches the point of a superstition. The type of dirt preferred is clay, which is found at the margins of rain pools. Half a pound of earth is sometimes consumed by a single person in one day. Addicts accumulate a reserve of choice dirt near their homes and carry pellets of earth with them in their clothing. This should be thought of in connection with the pollution of the soil described above.

In some regions cultural beliefs prevent the penetration of public-health and prophylactic devices. The Moslems are generally opposed to statistics, on the ground that Allah alone should know the exact number of human beings. In Tunisia the control of trachoma is difficult because the examination of female school children is prohibited. In Timor the inhabitants never plant more corn or rice than their ancestors did, since it is believed that to

increase the surface planted would be disrespectful to one’s father and grandfather. The living starve through respect to the dead.  

EXAMPLES OF DISEASES RESULTING FROM PARASITIC INFECTION

To illustrate the interrelationships of the various pathological and geographical elements discussed above, it may be helpful to consider examples of two-, three-, and four-factor complexes representing disease as a result of parasitic infection.

CHOLERA

Cholera is a bifactor complex produced when man swallows V. cholerae. What follows may depend on whether the juice of the stomach is high or low in hydrochloric acid. In the first case it may happen that V. cholerae is destroyed without having a chance to multiply. If the hydrochloric acid content is low, as it is after a meal, the bacillus pursues its way to the intestine, in which it multiplies enormously and liberates quantities of endotoxins, and from which it eventually reaches the outside world again. There the bacilli can be eaten anew in food polluted by the eater’s own fingers or those of his associates. Thus the multiplication continues until such time as the weaker individuals have been destroyed and only those with natural or acquired immunity remain, preventing multiplication of V. cholerae, and until such time as external circumstances—humidity, temperature, or factors yet undiscovered—force V. cholerae into dormancy. Unimmunized newcomers and favoring geographical factors may create the phenomenon called a “cholera epidemic.” The fate of man in this complex depends on his local and general health. The degree of immunization he possesses, the way he cooks his food, and the manner in which he eats it have also a direct bearing on the fate of the complex.

The problems of cholera in relation to geography are numerous and for many years have attracted researchers. Rogers, comparing cholera epidemics for more than 45 years in India, found a definite correlation between failure of the rains and cholera outbreaks, also between absolute humidity and recrudescence and spread of the disease. Chun, studying climate and cholera in various Chinese ports, found that each time an epidemic broke

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out the absolute humidity had risen above 0.4 inch, expressed as vapor pressure, which is the figure given by Rogers. However, the reverse does not hold true, and the absolute humidity may rise to this figure without the occurrence of an epidemic of cholera. Nor are the correlations between high humidity and cholera true everywhere. Lal has pointed out that they were not confirmed in Calcutta, Lahore, and several places in the United Provinces. In lower Bengal a heavy prevalence of cholera coincides with hot, dry weather. The correlation between epidemics and high temperatures seems to be better established than the correlation with humidity. It was so in Canton in 1937, Hong Kong, Shanghai, and Macao in 1938, and in Siam and Indochina in 1926 and 1927. However, unusual factors such as migration and influxes of refugees may alter the picture.

In some places, such as Siam, Indochina, and the Netherlands Indies, a lessening of the disease generally coincides with the onset of the rains, which dilute the concentration of germs in bodies of water and seem to play a part in bringing an epidemic to an end. Elsewhere heavy rainfall, especially after a long drought, may first increase the number of cases of cholera, because the rivers receive a mass of infection as a result of the downpours.

At one time Emmerich believed that there was a necessary correlation between the nature of the soil—richness in nitrates—and outbreaks of cholera epidemics. In their October, 1948, session, the joint Office International d’Hygiène Publique—World Health Organization study groups on cholera stressed the point that the presence of salt and organic matter is essential to the survival of cholera vibrios. The various microclimates and other ecological factors seem to have different influences in different places. This strongly suggests that the factor which governs the transformation of endemicity into epidemicity has not yet been discovered or that a number of factors operate against one another.

In the study of correlations distinction should be made between epidemic and endemic cholera. Two types of factors may contribute to an outbreak of epidemic cholera: (1) factors that cause the germ in nature or in man to change from a quiescent into a virulent form (such factors could be absolute humidity, presence of other germs, or the little-investigated electrical, magnetic, and radioactive forces); (2) factors that help the spread of the viru-

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lent germs (floods, rainfall, human conditions such as migrations, increased density of population, and pilgrimages, etc.).

The factors to be investigated in endemic cholera are those that keep the germ subdued. These may be positive (present) or negative (absent). Then, too, the ecology of the bacillus itself must be studied in relation to two different groups of factors: (1) the germ in man and degree of immunization, diet, bacteriological contents of the intestines (bacteriophage); (2) the germ in nature, where the chemical composition of the soil or of the water, irradiation, temperature, or humidity may affect the form and possibly the strain. If all these factors could be measured and charted in epidemic outbreaks and in the localities where cholera is endemic, and further study be made of the behavior of the bacillus under artificial climatic conditions, some new, enlightening fact might appear.

MALARIA

Let us now take a three-factor complex, such as malaria. Malaria is the human description of a collision between three living organisms: a protozoon, a mosquito, and man. A protozoon of the genus *Plasmodium* is injected into man’s system by the bite of a mosquito of the genus *Anopheles*. There it develops, passing through an asexual stage, which includes numerous divisions or schizogonies; finally, after several generations of asexual schizogonies, the parasitic form finds its way into a red blood cell as a sexual individual. There it grows until it fills the cell, which breaks up, liberating the sexual forms into the blood plasma. They are then either destroyed by the lytic powers of the plasma or taken up by an anopheles. Fertilization of the female then takes place, a new individual grows, dissociates the cells of the lining of the mosquito’s stomach, and divides into spindle-shaped cells called “sporozoites,” which infect all the tissues of the mosquito, including its salivary glands, whence they may be injected into man, and the cycle begins again.

The successful completion of this cycle, although similar in the various species of *Plasmodium*, is considerably affected by numerous factors, which differ for each species. The race of the human host makes a difference—white people imported into a malarial region offer a better medium than natives. The plasmodium is also affected by the immunity that may exist within the host, by his food and the state of his nutrition, and, eventually, by the medicine he takes. Climatic factors—temperature and humidity and probably many others—also influence the life chances of the plasmodium.

The correlation between the malaria complex and heavy rainfall was...
used by Gill\textsuperscript{28} in the Punjab in 1921 to forecast epidemic outbreaks. He showed that high relative humidity provided an environment favorable to the insect carrier, in both the larval and the adult stages. A high degree of correlation between rainfall and relative humidity existed during July and August, and the rainfall data of these two months were utilized as an index of humidity. A marked excess of July-August rainfall suggested the likelihood of an epidemic in the following autumn. Rainfall evenly distributed over these two months was regarded as more favorable for the development of epidemic conditions than heavy downpours toward the end of August, which might wash away and destroy the larvae. Floods during July and August, whether due to local rainfall or to inundation by rivers, were also considered as favorable for the occurrence of epidemic malaria. The spleen rate factor, the economic factor, and a special "epidemic potential" factor of each locality measured by the coefficient of variation of fever mortality over the period 1868–1921 were also used in the forecasting of malaria epidemics.\textsuperscript{29}

**SCRUB TYPHUS**

An example of a four-factor complex is the tsutsugamushi disease (also called "scrub typhus"). A mite of the subfamily Trombiculinae, a rodent (\emph{Microtus montebelloi} or a related species), a rickettsia (\emph{Rickettsia orientalis}), and man constitute the complex. Before it becomes a disease of man, it exists on the soil as a partial pathological complex, since the adult mite feeds on the juice of the leaves of young grass that has grown in patches of cleared jungle abandoned after temporary cultivation. The larval mite may be brought into the area by birds or by rats in search of food where man has been living. The larval mite sucks the rickettsia from the blood of the rat. It survives through the nymphal and adult stages into the next larval generation. Man enters the diseased area and is bitten. The symptoms he develops are called the "tsutsugamushi disease."

This example illustrates the importance of silent zones of disease—zones where all the elements of disease are present except man. If man steps into these silent zones without immunity and in a receptive condition, the phenomenon of disease occurs. These zones are widespread. The distribu-

\textsuperscript{28} C. A. Gill: Prediction of Malaria Epidemics, With Special Reference to an Actual Forecast in 1921, \emph{Indian Journ. of Medical Research}, Vol. 10, 1922–1923, pp. 1136–1143; \emph{idem}: The Genesis of Epidemics and the Natural History of Disease, New York, 1928.

\textsuperscript{29} Satya Swaroop: Forecasting of Epidemic Malaria in the Punjab, India, \emph{Amer. Journ. of Tropical Medicine}, Vol. 29, 1949, pp. 1–17.
tion of anophelines is world-wide, but malaria is conditioned by other factors also and thus exists only in certain places. The distribution of *A. aegypti*, which carries the virus of yellow fever, is considerably wider than the area where yellow fever actually occurs. The presence of rats is reported all over the world, but rickettsias or *P. pestis* has a limited geographical distribution; the three factors, man, agent, and vector, overlap only in certain areas. Rats live where they find food. Poorly protected or inadequate storage places attract rats, which carry rickettsias. In spring the farmer sows wheat, and in summer he harvests typhus. The mapping of these silent zones is of paramount interest to the study of medical geography. Of equal interest is the delimitation of endemic zones, where the complex maintains itself as a whisper between the loud outbreaks of epidemics. The passage from endemcity to epidemicity is one of the most important problems medical geography may help to solve.

**DISEASE RESULTING FROM WATER AND FOOD**

Hitherto we have dealt with diseases resulting from parasitic infection; now we come to the second main category of diseases—those resulting from properties inherent in the water and food of certain areas.

**Water**

Man obtains his water from various sources: underground, from wells and springs; surface, from rivers, lakes, pools, and ponds; atmospheric, from rain. Related to each of these sources are factors producing or inhibiting disease. Lack of iodine in the water of certain regions of Switzerland, for instance, and parts of the Andes, Yunnan, Manchuria, and Argentina, is correlated with the distribution of goiter.

The fluorine content of water governs several pathological conditions. If the fluorine content is lower than one part per million, dental caries is common; if much higher, mottled enamel, also called "dental fluorosis," occurs. In Argentina, in La Pampa, where the fluorine content of the water has been found to range from more than 0.2 milligram a liter to 20 milligrams, 70 per cent of the population over 20 years of age have dental fluorosis. In that drinking

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fluorosis. In southern Tunisia the fluorine content of the water is so high that drinking it causes the death of animals and produces exostoses in man.

Calcium deficiency in water, as we have seen, may play a role in the distribution of rickets and osteomalacia, or at least combines with other factors to produce them. In some parts of Algeria the water contains so much calcium phosphate and other minerals that it causes gastrointestinal disturbances and facilitates the production of stones. On the other hand, as is well known, mineral water is used for therapeutic purposes. In North China and Siberia a low calcium content of the water is found in the regions where Kashin-Beck’s disease (a shortening of the long bones and swelling of the short ones) occurs; in fact, the low calcium content exists not only in the water but also in the vegetables grown.

Water collected from rainfall has a lower mineral content than subsoil water. In the Gilbert Islands the natives obtain most of their water from wells; in the neighboring Ellice Islands rain water is collected. This may account for the fact that the Gilbert Islanders are found to have less dental caries than the Ellice Islands natives. Systematic study of the various waters man uses and correlation with the map of diseases might lead to new discoveries.

Food

A well-balanced diet provides calories for energy, a harmonious blending of fats, carbohydrates, and proteins for tissue building, and a satisfactory supply of minerals and vitamins. Few people of the world enjoy such a diet. In certain regions, such as southern India and Bengal, the diet, for economic and religious reasons, is entirely vegetable. As a result, the output of a Bengalese laborer is never, at best, equal to the output of a European or an American. The hill people, who live on a mixed diet of meat, vegetables, bread, and milk, show a completely different physical development. Two tribes living under similar climatic conditions but having different diets show a difference in development, aggressiveness, intelligence, and culture.


as well as in resistance to disease. This is illustrated by the famous study of Orr and Gilks of the Masai and Kikuyu tribes in Kenya.36

In certain regions of Eastern Europe, notably Hungary, cereals supply 90 per cent of the carbohydrate content of the diet and 70 per cent of the protein content. The reason is purely economic: more food per acre can be obtained in the form of cereals than in the form of vegetables or animal products.

Other factors influence the type of diet and contribute to the various forms of malnutrition. Land-tenure systems have a bearing. For example, in Egypt three-quarters of the population are agricultural, but only 7 per cent own two-thirds of the arable land. As a result, market demand and not individual preference determines the crops grown, and most of the people do not benefit from the food they raise. Where village ownership is the rule, there is likely to be a lack of incentive for fertilization and erosion control, and here again cash crops overshadow subsistence crops.

In the Balkans religious fasts occur so often and for such long periods as to impair seriously the health of the people: six weeks in Advent, six weeks before Easter, eight to thirty days at St. Peter’s feast, and every Wednesday and Friday throughout the year. This results in nutritional deficiencies among the children. During the spring fasts rickets, scurvy, and nutritional anemia are present in the young children, and tetany, xerophthalmia, and keratomalacia in the newborn.

In some places taxes levied on foods make prices prohibitive. In other places starvation is the result of poor distribution—no connections exist between two regions that grow complementary types of food.

In Hungary a correlation is found between the amount of land owned by a family and the amount of bread eaten. In families owning less than one acre bread provides about 66 per cent of the caloric diet. In families owning 10 to 20 acres it provides only 22 per cent; the rest is supplied by fats and animal protein. The low general consumption of meat in Hungary is surprising in view of the wealth in cattle, pigs, and sheep. A survey made in 1934–1935 of 5215 rural families showed that 45 per cent never ate green vegetables and 18 per cent ate no meat; 35 per cent consumed very little milk or none at all. As a result of this deficient diet only 32 per cent of the children of agricultural laborers, 25 per cent of those of artisans, 23 per cent of those of farmers owning their own land, and 8 per cent of those of labor-

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36 Orr and Gilks, op. cit.

37 L. G. M 1930; I. E. Nag of Middle Eur Rôle of Peasans Hungary, "Le Dietaries in Eu de la Hongrie 38 Harriett pp. 1023–1039
ers without long-term employment could be considered to be properly nourished.  

In places where cassava or sago is the main article in the diet, such as the Moluccas, vitamin B deficiencies are noticeable; the protein and fat content is low. Before the Moluccans came into contact with Western civilization, they complemented their diet with animal food, which provided proteins and fats—caterpillars, worms, maggots, and the like. Since they have been in contact with Western civilization, they have abandoned this part of their diet. As a result, these islands have become an important area of beriberi, pellagra, and bladder stones. Bladder stones are common in many tropical regions and can be explained in the following way. When the protein intake is low, the urea output in the urine is also low. Urea increases the solubility of calcium salts; consequently, on a low protein diet calcium phosphates in the urinary tract are likely to be precipitated. Also, a high protein diet causes the urine to be more acid, a low protein diet causes the urine to be more alkaline and thus decreases the solubility of calcium phosphates. Other geographical factors are also instrumental. Excess of vitamin D because of excess of sunlight may increase the urinary calcium because it increases the absorption of calcium. Lack of vitamin A causes the shedding of urinary epithelium, which forms the nuclei for stones.

Diet explains certain regional dental caries that has been traced to excess of cereals. In Iceland when the people subsisted on meat and fish, as they did for several centuries, there was no dental caries. When improved communications made import of cereals possible, rickets and dental caries appeared.

A spastic paralysis of the lower extremities, known as lathyrisn, is common in Abyssinia and Italy in people with low incomes who must subsist almost solely on chick-peas.

Social, economic, and geographical factors determine the diet of a region and its faults. The faults determine the types of diseases. Pellagra is associated with diets lacking nicotinic acid. It is common in Rumania, Bulgaria,


northern Italy, certain parts of Egypt, and the southern regions of the United States. Rickets is associated with lack of calcium, lack of sunshine, or both.

Lack of sunshine may be self-inflicted. In China women have had their feet bound for many generations. This practice prevented them from taking any outdoor exercise. Living permanently inside their houses, they were, and in some places still are, condemned to late rickets from the time of their claustration, which their many pregnancies gradually transformed into permanent osteomalacia.39

Eating habits are another aspect of culture that has a bearing on the pathological picture. However bad, unsanitary, or unhealthful such habits may be, they are so firmly ingrained that even during famines it is impossible to change them. This was found to be bitterly true in the last famine in Bengal (1945), when many persons starved rather than eat the unknown dehydrated food furnished by relief workers. If wheat is brought into a rice-eating district, most of the people will not eat it; in other places many of the faithful would rather die of starvation than drink milk or eat beef.

DISEASES RELATED TO CERTAIN SPECIFIC FOODS

Another approach to the study of the geographical distribution of disease could be the study of the relationships between certain diseases and certain diets. The diseases could of course be caused by parasitic infection, by the nature of the food ingested, or by both. Let us now give a few examples of these correlations.

Milk

The diseases that derive from the consumption of milk depend partly on the milk itself and partly on the standard of living of the people who consume it. Where the standard is high, the milk is either pasteurized before it is distributed or boiled at home, and the incidence of milk-borne diseases, such as septic sore throat, scarlet fever, and brucellosis, is low. On the other hand, where the standard of living is low, the incidence of milk-borne diseases is high. Further, milk can be polluted with water, with all its infectious possibilities.

Usually, places where cow’s milk is consumed are places of high economic standards, and such milk-borne diseases as occur are accidents that have slipped through the tight network of a good public-health system. The

areas of milk-borne diseases are chiefly those where goat’s milk or camel’s milk is consumed. In the Mediterranean basin we find many foci of brucellosis (Malta fever) and tuberculosis, because of the consumption of raw goat’s milk, or diseased cow’s milk, or unfermented cheese made with goat’s milk. Poor people in Malta, Sicily, Elba, and the eastern basin of the Mediterranean live in close contact with their animals. The foci of brucellosis change constantly, partly because farmers try to sell animals that have aborted as a result of infection, and the disease is thus spread into uninfected areas.

In Somaliland camel’s milk is preferred because of its antiscorbutic properties, but it seems to cause constipation, which is a common ailment among nomads living in this milk. In India it is usual before buying milk to dip a finger into it to ascertain the quality. In Africa, the West Indies, and other hot regions where milk has to be transported over some distance, it is occasionally sold sour, with a consequent high bacteriological content.

**Fish**

Fish can cause human disease both by contact and by ingestion. Contact may be an accident, as when divers and sponge fishermen are bitten. More often fish is a source of disease because it is eaten insufficiently cooked. Some fish (*Tetraodon maculatum*) found near the shores of Japan and the South Pacific islands contain a poison related to muscarine; it is tasteless and odorless and is not destroyed by cooking.

Fish is the intermediate host for a number of helminths, such as *D. latum*; crayfish or crabs for *Paragonimus westermani*. These infestations are common in Japan, Korea, and Formosa, where people eat raw fish, but they can also be found in China, Central Africa, and South America. Primitive tribes of Sakhalin subsist almost entirely on fish. It is buried in pits and covered with earth in summer for use in winter; as a result, one-half to one-third of the population are infested with *D. latum*. In Finland also, a large consumption of fish results in heavy infestation with *D. latum*; the average incidence is 20 to 25 per cent. Oysters and mussels in polluted waters in the Mediterranean spread typhoid among the poorer people, who cannot buy other animal protein and find the shellfish cheap and nourishing food.

**Rice**

Rice is the food consumed by one-half of the inhabitants of the earth, in certain regions together with other foods, in most regions with whatever
seasoning can be afforded—for example, a little fish—and very often nothing else. The diseases associated with rice can be classified in two groups: those related to cultivation, and those related to consumption.

Asiatic schistosomiasis belongs to the first group. It is caused by *Schistosoma japonicum*, which finds in *Oncomelania* its intermediate host. This mollusk is adapted to rice fields flooded with quiet water. When the cercariae come out of the snail, they penetrate through the skin of the farmer as he wades in the mud of his fields. Later they develop into the adult form and lay their eggs under the mucosa of the intestine, from which they are restored to nature through the conveyance of the feces.

The prevalence of malaria is closely associated with the cultivation of rice. Although this statement is true in general, it is qualified by the fact that each region has its own malaria vector and each vector, as we have seen, its own living habits. In the Philippines, for instance, *Anopheles minimus* is the main malaria vector. Its breeding places are the edges of small running streams in the foothills; it is seldom found in stagnant pools. On the other hand, *A. subpictus*, which breeds in the stagnating waters of the rice fields, is a weak carrier, and it has therefore been thought possible to combat malaria in the islands by developing rice culture.49

In Malaya the absence of malaria in the rice districts and its prevalence in the hill countries support this view. In Indochina malaria is associated with rice cultivation in some places and not in others. Kerandel41 has shown that the type of cultivation determines the type of mosquito. If the water in the rice fields is allowed to remain stagnant for long periods, it becomes unfavorable for the breeding of the local malaria vector; but if the rice fields are in terraces or if the water is moving, malaria-carrying mosquitoes breed prolifically.

Robertson and Chang, working in Shanghai, have pointed out that *Aedes hyrcanus* is found in rice fields much more frequently than in irrigation ditches or pools. They compared rice growing by transplantation and by broadcasting seed. The transplantation method shortened by one month the flooding of the rice fields and thus reduced by one month the chances of anopheline breeding. They also found that the various steps of cultivation—preparation of land, preparation of, and work in, the nursery bed, irrigation, fertilizing, hoeing, and weeding—and flowering and harvest all had an influence on anopheline breeding and malaria. The preparation of the land is unfavorable

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for anopheline breeding during the first two weeks, when the water is being absorbed by the dry soil; later, when the water remains in the saturated field, some anopheline breeding begins, but it is soon interfered with by irrigation and by fertilization with green manure and night soil. Still later, the hoeing and weeding pollute the water, which becomes turbid, a condition that considerably affects the development of the larvae. After the hoeing is done, the rice fields are flooded and left undisturbed. Enormous anopheline breeding ensues and continues during the flowering season, when the water becomes stable and clear five to eight inches deep. Then aquatic plants begin to grow rapidly between the rice shoots, again disturbing the larvae, so that the breeding goes on only along the sunny margins (shade offers an unfavorable environment for many malaria-carrying mosquitoes, and the planting of trees in rice fields has been advocated to combat malaria). After the flowering, the water is withdrawn, and the breeding quickly ceases. After harvesting, breeding is determined by the amount of rainfall; if rainfall is heavy, breeding occurs. The peculiarities of the malaria vectors and agricultural techniques may be put to good use to curb the spread of the disease.

Rice consumption is related to a specific disease, beriberi. This is caused by the lack of vitamin B, resulting from the removal of the envelope that contains the vitamin by the grinding and polishing of the rice. In countries where rice is parboiled before pounding or where rice is not the only cereal eaten, the disease is less prevalent. Beriberi has caused a serious health problem in Japan. The present policy is to wash and hull the rice only to the extent of seven-tenths of its weight and to recommend the admixture of barley.

Rice fields are also linked with diseases transmitted by rats, many species of which live in the rice swamps. In Italy, for example, leptospirosis transmitted by rats is a distinct disease of the rice fields.

**The World Distribution of Disease**

If we attempt to map the pathological regions of the world with the foregoing in mind, we find that the main divisions appear at first glance to be correlated with local diets, cultures, religions, and standards of living. The pattern is not clear-cut, and many of the pathological regions overlap, but the broad picture shows where a disease is prominent.

In the Far East, encompassing the shores of Siberia, Korea, northeast and southeast China, and including the chain of islands that link the Kamchatka Peninsula to Formosa, is a vast temperate region where uncooked crab and
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- Leptospirosis: A group that is caused by the bacterium Leptospira interrogans. It is transmitted through the bite of infected animals, usually through the bite of a rat. Symptoms include fever, muscle pain, and jaundice. The disease can be treated with antibiotics.

- Angiostrongyliasis: A lungworm infection that is transmitted to humans through the consumption of undercooked or raw mollusks, particularly snails. Symptoms include cough, chest pain, and fever. The disease can be treated with praziquantel.

- Trypanosomiasis: A disease caused by the parasitic protozoan Trypanosoma brucei, which is transmitted to humans through the bite of infected tsetse flies or other blood-sucking insects. Symptoms include fever, headache, and lymphadenopathy. The disease can be treated with trypanocidal drugs.

- Schistosomiasis: A disease caused by the parasitic flatworm Schistosoma mansoni, which is transmitted to humans through contact with infected freshwater. Symptoms include diarrhea, blood in the stool, and abdominal pain. The disease can be treated with praziquantel.

- Guinea Worm: A disease caused by the parasitic nematode Dracunculus medinensis, which is transmitted to humans through contact with infected freshwater. Symptoms include swelling and pain in the legs and feet. The disease can be treated with surgical extraction.

- Filariasis: A disease caused by the parasitic nematode Wuchereria bancrofti, which is transmitted to humans through the bite of infected mosquitoes. Symptoms include swelling of the limbs and testes. The disease can be treated with diethylcarbamazine.
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<th>Latitude</th>
<th>Longitude</th>
<th>Neobactery</th>
<th>Water drainage</th>
<th>Rainfall &amp; humidity</th>
<th>Bacteremia</th>
<th>Pressure</th>
<th>Temperature</th>
<th>Winds</th>
<th>Radiation</th>
<th>Magnetism</th>
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<th>Soil conditions</th>
<th>Income</th>
<th>Population density</th>
<th>Housing</th>
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<th>Drug addiction</th>
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<th>Relation to other diseases</th>
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<td>Rodent</td>
<td>Pediculus</td>
<td>R. prowazeki</td>
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| FOUR-FACTOR COMPLEXES             |          |           |            | +               | +                 |            |          |             |       |            |           |               |           |           |               |        |                  |         |           |           |     |                |                |            |           |           |              |             |           |         | Fish are the larva of the fish. For example, salmon affects man with regard to malaria but not with regard to clamorine or encephalitis. | Man | Salmon |

| Scrub typhus                      |          |           |            | +               | +                 |            |          |             |       |            |           |               |           |           |               |        |                  |         |           |           |     |                |                |            |           |           |              |             |           |         | The adult mite lives on a certain type of grass, such as the coarse grasses growing on abandoned estates. | Man | Scrub typhus |
| Tularemia                         |          |           |            | +               | +                 |            |          |             |       |            |           |               |           |           |               |        |                  |         |           |           |     |                |                |            |           |           |              |             |           |         | Dermaentor is a vector and also reservoir, since it is the only host the cercariae can penetrate. The disease may be transmitted directly. | Rodent | Dermaentor, R. tularemia |
| Trematode diseases Type: Clonorchiasis |          |           |            | +               | +                 |            |          |             |       |            |           |               |           |           |               |        |                  |         |           |           |     |                |                |            |           |           |              |             |           |         | Certain trematodes do not require a second intermediate host. The cercariae erupt and attach themselves to certain types of aquatic vegetation. | Man | Snail |
| Cestode diseases Type: D. latum   |          |           |            | +               | +                 |            |          |             |       |            |           |               |           |           |               |        |                  |         |           |           |     |                |                |            |           |           |              |             |           |         | The spargana of similar parasites cannot be distinguished. | Man | Copepod |
| Bubonic plague                   |          |           |            | +               | +                 |            |          |             |       |            |           |               |           |           |               |        |                  |         |           |           |     |                |                |            |           |           |              |             |           |         | Only bubonic is considered here, since pneumonic plague is usually transmitted from man to man. | Redent | Flea |
| Yellow fever                     |          |           |            | +               | +                 |            |          |             |       |            |           |               |           |           |               |        |                  |         |           |           |     |                |                |            |           |           |              |             |           |         | Yellow fever seems to be maintained by a dual cycle: jungle yellow fever where the virus is maintained in the primate by a mosquito (Haemagopit). Human reservoirs and household yellow fever spread by the cycle of man-mosquito (Aedes). | Man | Mosquito |
| Leishmaniasis                    |          |           |            | +               | +                 |            |          |             |       |            |           |               |           |           |               |        |                  |         |           |           |     |                |                |            |           |           |              |             |           |         | This information is debatable whether the various leishmaniasis should be considered a three- or four-factor complex. In China the dog seems to be an important reservoir of the disease. | Man | Phlebotomus |

*It has seemed preferable, in working out this table, to consider man only in relation to other factors and not as an isolated element, since his response to the various geogens may make him more or less receptive to the actions of the different agents of the complex. For example, housing affects man with regard to malaria but not with regard to clamorine or encephalitis.
fish are main articles of diet. Here flourish the liver fluke, *Clonorchis sinensis*; the lung fluke, *P. westermanii*; and the intestinal tapeworm, *D. latum*—all of them related to crab or fish.

Westward over the vast expanses of China, India, and Arabia, the shores of the Red Sea, Egypt, and tropical Africa, a region covering about one-quarter of the land surface of the earth, we find what may be called the "empire of soil pollution." Here dense agglomerations of humanity live on dirt, eat dirt, and produce dirt. Here are all the diseases of the bowels—amoebic dysentery, bacillary dysentery, all the intestinal worms. Moreover, in the Yangtze Valley, the Ganges Valley, Madras, and Bombay we find the centuries-old endemic foci of cholera. The land of soil pollution is also the land of rice; and where rice is grown and eaten—except for a few spots where it is parboiled before grinding—the people have beriberi.

The Mediterranean basin, the land of goat's milk, is also the land of brucellosis. In Africa we have diseases correlated with the tsetse fly, the trypanosomiases. The Atlantic shores of Africa and the shores of Central and South America are the realm of yellow fever, which, however, does not coincide with the empire of its vectors, whose domain extends practically all over the tropical and subtropical world.

In the Americas we find two different pathological regions—Central and South America, and North America. The contrast between them is striking. In most areas of the southern region the pathological picture is still raw, whereas in the north man's labors have altered the picture considerably. Other pathological patterns, such as arthritis, cancer, and high blood pressure, seem to occupy the forefront.

**A Program of Research**

To illustrate the foregoing, the accompanying tabulation has been set up.

Diseases taken as examples are classified in two-, three-, and four-factor groups and listed in horizontal columns. Geogens are listed in vertical columns. When a correlation between a pathogen and a geogen seems positively established, a plus sign is inscribed in the square corresponding to the intersection of the columns. A minus sign indicates that no correlation appears to exist at the present time. A question mark shows that the correlation needs to be investigated.

The present list of geogens is completely arbitrary. Other factors could be added; some could probably be condensed.

The tabulation as a whole is an attempt at a census of our present knowl-
edge of medical geography. Some of the unexplored correlations could be investigated in the field or in experimental stations where climatic geogens could be artificially produced.

A program of research should comprise:

1. A census of what is known and a discussion of every problem suggested by the tabulation.

2. The study of a disease, taken as an example of the endemic-epidemic type, against its environment.

3. The study of a region with reference to the diseases it produces. This should include sample studies of population, in order to work out a reliable statistical method for the computation of the prevalence of diseases. Such a plan is now being developed at the American Geographical Society.

**UNDERDEVELOPED COUNTRIES AND MEDICAL GEOGRAPHY**

The President of the United States has declared his intention to lead the country into a new program for the advancement of backward areas of the world. When the time comes to enforce this policy, there will be a demand for facts about these backward areas. The question will be asked, what makes people backward? What causes countries to be underdeveloped? For much of the tropics, at least a partial answer can be given. The soil produces poor food, the pathogens cause poor health, both are the cause of poor working efficiency, all operating in a vicious circle. An outsider breaking into the environment would be fed its food and inoculated with its parasites, unless he brought with him the techniques by which Western civilization has triumphed over difficulties of nature.

In China, Indochina, India, Central Africa, and Central America, for instance, parasites and food combine to give the inhabitants a chronic anemia, which causes anoxia of organs and tissues. If unusual effort or exertion is made, asphyxia soon results. The people most heavily infested with parasites are also underfed. With these terrific handicaps, they cannot develop their intelligence and culture, cannot organize agriculture profitably or develop commerce and industry or the arts of social living. They are, consequently, in no position to establish institutions by which they could raise their standard of living, organize sanitary campaigns, and achieve public health. Since they cannot get rid of their most despotick tyrants and oppressors, the intestinal worms and blood parasites, they are tied down by their physical condition to their backward status. Medical geography could become a preliminary step to the redemption of backward countries throughout the world; for, in
MAP OF THE WORLD DISTRIBUTION OF CHOLERA

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The accompanying map of cholera represents the second plate of the Society’s projected “Atlas of Diseases.” Because its epidemiology is rich in geographical correlations, cholera was given high priority on our list.

Although cholera has been known to exist in India since earliest history, it struck the outer world for the first time, so far as we know, in the nineteenth century. Before 1816 epidemics occurring in other parts of Asia had taken place during certain not been identified or traced, and there is no evidence that outbreaks had occurred in Europe or in the Western Hemisphere before the so-called “second pandemic” in 1832.

The epidemiology of cholera raises several problems, which from the first four pandemics geographer’s point of view can be summarized thus. Under certain circumstances, some of which are known and others not, the disease breaks out in 1923, when Epidemic outbreaks have occurred in different climates, though some parts of the world (see map) have remained completely unaffected. Under other circumstances, some of which are understood and others not, cholera remains quiescent, showing its presence by continuous small certain places between numbers of cases, which at certain times and during certain seasons become cholera presence by epidemics of various morbidity and mortalities. This type of cholera is these two years. Perhaps confined to certain districts of India. For these reasons we distinguish the each unit. The study of epidemic or occasional cholera from that of endemic or permanent on a yearly basis. For cholera. Occasional cholera is closely linked to factors of human geography, has been shown.

It correlates with the density of population, permanent or transient. When large numbers of susceptibles are gathered together, as on pilgrimages, those coming from cholera-infested areas bring the disease with them, spreading it everywhere on the way. They contaminate their fellow worshipers, who in turn spread the pestilence as they return to their homelands.

As one has to eat or drink the germ of the disease to become contaminated, the cultural and religious habits of human groups, the social customs and amenities, influence to a great extent its areal distribution and morbidity.

The disease is also linked to factors of economic geography, spreading through the inhabited world along the routes of commerce, by caravans, shipping lines, or railroads, at a speed that is sometimes, but not always, proportionate to that of the carrier. (Compare the slow advance by caravan of the first three pandemics with the rapid advance by steamship and rail of the fourth.)

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1 With the exception of...