Section of Comparative Medicine

[*February* 28, 1934]

Malaria from a Zoological Point of View

By Sir RICKARD CHRISTOPHERS, C.I.E., M.B., F.R.S.

ABSTRACT.—Protozoal parasites occurring in the red cells of mammals are: Hepatozoon, Babesia, Theileria and Plasmodium. The frequency with which these forms occur differs considerably in the different mammalian orders. But whilst there is a relationship apparent between the mammalian stem and the form of parasite, there appears to be an even closer association with the type of blood-sucking arthropods which the mode of life of the animals in a particular stem favours. Ungulates in the days of their greatest development chiefly roamed in herds over rather arid country not favouring mosquitoes, but suitable for tick infestation. Monkeys and bats are more likely to live in a humid sheltered environment where they are more liable to attack by mosquitoes.

Knowledge of the plasmodial parasites of monkeys has up to recently been very meagre, but from the work of Sinton and Mulligan it appears certain that in the main distinct parasites occur respectively in the Oriental and Ethiopian regions, just as the genera of monkeys under present nomenclature are mainly confined to one or other of these zoogeographical realms. *P. brasilianum* occurring in the Neotropical monkeys is a distinct parasite from any Old World form. None of the monkey parasites are probably really very close to those of man.

The apes evolved as part of a great Pliocene fauna, and their remains occur in Europe, Egypt and India. The progenitors even of the present-day African forms are found in the Indian deposits. In the gorilla and chimpanzee, forms of plasmodium, so far described, appear to be very similar to those of man, including the characteristic crescent forms.

In the main the races of men are essentially Pleistocene and Palæarctic. They none of them form true Neotropical, Australasian or Oriental man in the zoological sense, but it is less certain there is not a relationship in the case of the Ethiopian region. The parasites of malaria in any case do not show any apparent relationship to the usual zoogeographical realms, and their distribution and prevalence appear to be determined on quite other grounds than those normal to zoological distributions. *P. vivax* occurs almost throughout the world within the July and January isotherms of 60°. *P. falciparum* is limited by the isotherms of 70°. Quartan is believed by Knowles and Senior White to have a peculiar geographical distribution. Frequency of occurrence is, however, entirely different from distribution, and this parasite probably also has its distribution determined by factors other than those usually concerned in the distribution of animal forms of life. Among other features it appears to be associated with areas of severe endemicity, and becomes conspicuous when transmission is temporarily in abeyance. Mer has recently shown that it has a very slow development in the mosquito, and this may explain some of its peculiarities.

The parasites *P. tenue* and *P. ovale* are so far recorded only from India and East Africa respectively. Observations regarding the occurrence of these forms are much needed.

RÉSUMÉ.—Les parasites protozoaires qui se trouvent dans les globules rouges des mammifères sont : Hepatozoon, Babesia, Theileria et Plasmodium. La fréquence des différents parasites varie beaucoup selon les ordres des mammifères. Quoiqu'il existe une relation apparente entre la souche mammifère et le type de parasite, une relation encore plus étroite semble exister entre le type d'arthropode suceur de sang et la mode de vie des animaux d'une certaine espèce. Les ongulés, pendant la période de leur plus grand développement, erraient en troupeaux à travers les plaines arides peu favorables aux moustiques, mais favorisant l'infestation par les tiques. Les singes et les chauves-souris demeurent probablement dans des lieux humides et abrités, où ils sont plus exposés à l'attaque des moustiques.

Nos connaissances sur les plasmodes des singes ont été très maigres jusqu'à present, mais d'après les travaux de Sinton et Mulligan il semble certain qu'en général des parasites différents sont trouvés dans les régions orientale et éthiopienne, de même que les genres de singes, d'après la nomenclature actuelle, sont en général limités à l'une ou l'autre de ces régions zoogéographiques. *P. brasilianum*, trouvé dans les singes néotropiques, se distingue de tous les types de parasite de l'ancien monde. Il est probable qu'aucun des parasites du singe se rapproche beaucoup de ceux de l'homme.

Les singes se sont développés comme une partie de la grande faune Pliocène, et leurs restes ont été trouvés en Europe, en Egypte et aux Indes. Même les ancêtres des types africains actuels se trouvent dans les excavations aux Indes. Les types de plasmode trouvés jusqu'ici chez les gorilles et les chimpanzés semblent se rapprocher beaucoup de ceux trouvés chez l'homme, y compris les formes caractéristiques en croissant.

En général les races humaines proviennent essentiellement des époques pléistocène et paléo-arctique. Aucune d'elles ne représente le vrai homme néotropical ou australasien ou oriental dans le sens zoologique, mais l'absence de relation est moins certaine dans le cas de la région éthiopienne. En tout cas les parasites du paludisme ne montrent pas de relations avec les régions zoogéographiques, et leur distribution et leur fréquence semble être déterminée par des principes entièrement différents de ceux qui agissent normalement dans la distribution zoologique. *P. vivax* existe à peu près partout entre les isothermes de 60° F. en janvier et juillet. *P. falciparum* est limité par les isothermes de 70° F. Knowles et Senior White croient que le parasite de la fièvre quarte a une distribution géographique particulière. Toutefois la fréquence et la distribution sont des choses entièrement différentes, et la distribution de ce parasite est probablement aussi déterminée par des facteurs différents de ceux qui agissent dans la distribution des animaux. L'une de ses caractéristiques est qu'il paraît être associé avec des régions de haute endémicité, et se fait remarquer quand la transmission est temporairement en suspens. Mer a démontré récemment qu'il se développe très lentement dans le moustique, ce qui explique peut-être quelques-unes de ses particularités.

Jusqu'à présent *P. tenue* a été trouvé seulement aux Indes et *P. ovale* en Afrique orientale. Des observations sur la distribution de ces deux types sont très nècessaires.

ZUSAMMENFASSUNG : Die protozoische Parasiten die in den roten Blutkörperchen der Saugetieren vorkommen sind : Hepatozoon, Babesia, Theileria und Plasmodium. Die Häufigkeit dieser Formen ist in den verschiedenen Saugetieren sehr verschieden. Während eine scheinbare Beziehung zwischen dem Stamm der Saugetieren und der Form der Parasiten besteht, scheint diese eine viel nähere Beziehung zu besitzen mit den blutsaugenden Arthropoden die durch die lebensweise der Tiere eines bestimmten Stammes bevorzugt sind. Die Ungulaten wanderten zur Zeit ihrer grössten Verbreitung über eher trockene Ebenen, die den Schnaken nicht, dagegen aber den Schecken günstig waren. Affen und Fledermäuse wohnen gewöhnlich in einer feuchten, geschützten Umgebung, wo sie dem Angriff von Schnaken mehr ausgesetzt sind.

Unsere Kenntnis der Plasmodien der Affen ist bis jetzt sehr gering, aber nach Sinton und Mulligans Arbeiten scheint es sicher zu sein dass verschiedene Parasiten in der orienental bzw. äthiopische Regionen, ebenso wie die Affen, nach der heutigen. Nomenklatur, meistens auf eine oder die andere von diesen zoogeographischen Gebieten beschränkt sind. Das in den

neotropischen Affen vorkommende *P. brasilianum* unterscheidet sich von allen Parasiten die in der alten Welt vorkommen. Wahrscheinlich sine keine von den Affenparasiten den menschlichen Parasiten sehr nahe verwandt.

Die Affen haben sich als Teil der grossen Pliozänfauna entwickelt, und man findet ihre Resten in Europa, Ägypten und Indien. Die Vorfahren selbst der heutigen afrikanischen Affen sind in den indischen Niederschlägen zu finden. Die bisher in den Gorillen und Schimpanseen beschriebenen Plasmodiumformen scheinen den menschlichen Formen sehr ähnlich zu sein, einschliessend der charakteristischen Halbmondformen.

Im ganzen sind die menschlichen Rassen wesentlich Pleistozan und Palaarktisch. Es gibt keine echte neotropische, australasische oder orientale Menschen im zoologischen Sinne, aber in dem Äthiopischen Gebiet ist es weniger sicher dass keine Beziehung besteht. Jedenfalls zeigen die Malariaparasiten keine deutliche Beziehung zu den gewöhnlichen zoogeographischen Gebieten, und ihre Verbreitung und Häufigkeit scheinen auf ganz andere Faktoren begründet zu sein als die normalen zoologischen Verbreitungen. *P. vivax* wird fast in der ganzen Welt zwischen den Januar- und Juli-Isothermen von 60° F. gefunden. *P. falciparum* ist durch die Isothermen von 70° F. eingeschränkt. Knowles und Senior White glauben dass das Quartanfieber eigenartig verbreitet ist. Häufigkeit und Verbreitung sind jedoch ganz verschieden, und die Verbreitung dieses Parasites ist wahrscheinlich auch durch andere Faktoren bestimmt als andere Lebensformen. Unter anderen Charaktere scheint er mit Regionen grosser Endemizität verbunden zu sein, und er wird auffällig wenn die Übertragung vorübergehend nicht aktiv ist. Mer hat in letzter Zeit gezeigt dass dieser Parasit sich in den Schnaken sehr langsam entwickelt, was einige seiner Eigentümlichkeiten vielleicht erklärt.

P. tenue ist bisher nur in Indien, *P. ovale* nur in Ostafrika gefunden. Beobachtungen über diese zwei Parasiten sind sehr notwendig.

MAN, along with many of the lower animals, is subject to the invasion of his red blood corpuscles by certain parasitic protozoa. Infection with *Plasmodium* in man constitutes the important disease, malaria. Infection with *Piroplasmidæ* in cattle gives rise to some of the most important diseases dealt with by veterinary science. Other parasites of this kind are found in various domestic and wild animals, among which we may specially mention the parasites giving rise to monkey malaria.

Except for a few peculiar forms, about the nature of which little is known, protozoan parasites of the red cells are all at present considered to fall in the Class Sporozoa, Subclass Coccidiomorpha. In other words, as suggested by Wenyon, 1926 [1] for the Hæmosporidiidæ, they are coccidia which have taken to parasitism of the red cells of the blood instead of the more usual epithelial host cell favoured by these parasites. Judging by the accepted classification of the Sporozoa, this habit is one that has developed more than once in the course of evolution. In every case this habit is associated with, and has probably necessitated, the passing of a part of the life-cycle of the parasite in an intermediate invertebrate host.

The three chief groups of red-cell parasitic sporozoa are, the Hæmogregarinidæ, the Hæmosporidiidæ and the Piroplasmidæ. In general, the Hæmogregarinidæ are commonest in the lower vertebrates, such as reptiles and fish, and have only been known relatively recently in mammals since Balfour, 1905 [2], described a typical form in the jerboa. Of the two families of the Hæmosporidiidæ, the Hæmoproteidæ are very common in birds, but are known also in reptiles and the Plasmodidæ are perhaps more especially mammalian forms, though they are also common parasites of birds and a few forms seemingly of this type are known in lizards. The Piroplasmidæ are entirely mammalian.

The genera occurring in mammals are: (in the Hæmogregarinidæ) *Hepatozoon*, including all the hæmogregarine-like forms attacking either the red cells or the leucocytes; (in the Piroplasmidæ), *Babesia* and *Theileria*; (in the Hæmosporidiidæ), *Plasmodium*.

In the accompanying table, compiled from the list of mammalian hosts given by Wenyon, 1926 [3], are given under the different mammalian orders, the number of species in which parasites of each of these kinds have been recorded. The exact

	Hepatozoon	*Babesia*	*Theileria*	*Plasmodium*
Monotreme			1	
Marsupial	4			
Insectivora	1	3		2
Chiroptera		3		14
Primatia	2	2		26
Rodentia	29	14		5
Carnivora	6	11		2
Ungulata	2	30	3	2
Edentata		1		

numbers should not be given too much weight, but the table gives a good general idea of the distribution of these parasitic forms in the different mammalian stems. In marsupials, so far only *Hepatozoon* has been described, though a *Theileria* is recorded in the Monotreme *Echidna*. Possibly, however, the number of marsupials examined has not been very great. Among the placentate mammals *Hepatozoon* occurs most noticeably in the Rodents and also in the Carnivora. *Babesia* (with *Theileria*) is almost the only form occurring in Ungulates, though at least two Plasmodia and two Hepatozoa appear to be authentically recorded in this order. Carnivora and also Rodents rather frequently show *Babesia*-like parasites, as also the Insectivora and Chiroptera. The Bats and especially the Primates are very noticeable for the frequency with which they show *Plasmodium*.

The very early mammals were of aplacentate or marsupial type. The placentate orders are known from the Eocene (Zittel, 1925 [4]). The most primitive of the early prototypes were the Primitive Insectivors from which are derived the existing Insectivors, the Bats, Primates and Rodents. The Carnivora arose from the Creodontia, a primitive carnivorous type, now extinct, having affinities with the Primitive Insectivors. The Ungulates are derived from another primitive stem, the Condylarthra, which had affinities with the Creodonts and in some cases with the Rodentia. In general, stems much as at present existed throughout the tertiary, some, however, becoming extinct.

It is possible perhaps to regard these derivations as giving some explanation of the relative prevalence of type of parasite. Thus one might explain the occurrence of *Babesia* in both Ungulates and Carnivora as due to both these stems arising from creodont ancestors, whilst *Plasmodium* in Bats and Primates might be ascribed to the common insectivor ancestry of these orders. It cannot be said that such explanations are very convincing. A more likely line of approach is suggested if we consider the intermediate invertebrate hosts with which stems are likely to be more especially associated.

The Ungulates and Carnivora are notably tick carriers. The vast droves of game, which we may visualize as occurring when the ungulates with their attendant carnivors were undergoing evolution, would lead to a life in the main remote from water, probably in steppe- or park-like country. Under such conditions the maximum facilities are likely to be given for the evolution of parasites based on the tick as intermediate host. Birds, bats and monkeys tend to live among trees, in wooded and even forest country and would be more brought into contact with mosquitoes. Allowing that plasmodial parasites once specialized to a particular mammalian stem would tend to be restricted to this stem, the idea that evolution of parasitic forms was from the intermediate host seems to be most in keeping with the known facts. It also receives support from the consideration sometimes pointed out that it is usually the sexual stage which is passed in the invertebrate host. From this point of view, then, we may regard man as continuing to harbour parasites of his red cells

which were acquired at some remote period when his ancestors or precursors, ape, monkey, lemur or primitive insectivor, lived in close association with anopheles, probably in the forest. It remains to be seen whether we can glean anything from what is known of plasmodial forms in the primate stem as to the probable source from which the parasites of man came. The data we possess suggests that it was much more likely to be from some part of the primate stem than any casual picking up of a parasite from outside this stem.

Monkey malaria.—The lemurs are the most primitive of the primates. Their remains are known from the Eocene in Europe and America, but they disappear from the fossil record until they are found again in Pleistocene and recent times in Madagascar. A few recent forms such as *Tarsius*, occur also elsewhere. So far as I have been able to ascertain, no plasmodial or other red-cell parasites have been described from lemurs. Anaplasma-like bodies are described by Dodd, 1913 [5], but are not considered by this author to be of parasitic nature.

The remaining primates are divided into the Catarrhini (Old World apes and monkeys) and the Platyrrhini or New World monkeys and marmosets. These are two distinct stems, the latter isolated at an early period and now forming part of the Neotropical or South American fauna. Fossil monkeys are known from the Oligocene in Egypt (*Parapithecus, Moeripithecus*). *Oreopithecus* is known from several localities in Europe in the Upper Miocene. A number of fossil catarrhine forms occur in the Pliocene in Europe, Asia and Africa.

The existing Old World monkeys include a number of genera, the nomenclature of which has become so confused that it is sometimes difficult to trace what genus is intended by an author. Recently, a revision of the parasite-bearing forms has been made by Stiles and Nolan, 1929 [6], whose nomenclature most authors dealing with monkey malaria now follow. Since a good deal of interest is at present being taken in monkeys on account of monkey malaria, yellow fever, etc., I give a list of generic names according to Stiles and Nolan, with the English names of the monkeys and their rough distribution.

CATARRHINI (Old World Apes and Monkeys).

Anthropomorpha (Higher Apes).

Pan	Chimpanzee	Africa
Gorilla	Gorilla (2 species)	,,
Pongo	Orang-Utan	Borneo, Sumatra
Hylobates	Gibbons (4 to 5 species)	India, Sumatra, Borneo, etc.
Symphalangus	Siamang	Sumatra

Cynomorpha.

Colobus	Guereza Monkeys	Africa
Pygathrix	Langurs	India, Sumatra, Java
Papio	Baboons	Africa
Theropithecus		Abyssinia
Macaca	Barbary Ape	North Africa
Silenus (Macacus)	Macaques	India, Sumatra, China, etc.
Cercocebus	Mangabeys	Africa
Cercopithecus	Guenon Monkeys	,,
Erythrocebus	,, ,,	,,

PLATYRRHINI.

Cebidæ (Spider Monkeys).

Aotus	Titi Monkeys	S. America
Callicebus	Saki Monkeys	,,
Pithecia	Uakari Monkeys	,,
Cacajao	Squirrel Monkeys	,,
Saimiri		,,
Cebus	Capuchin Monkeys	S. and C. America
Lagothrix	Woolly Spider Monkeys	S. America
Brachyteles	,, ,, ,,	,,
Ateles	Spider Monkeys	S. and C. America
Alouatta	Howler Monkeys	,, ,,

CATARRHINI (Old World Apes and Monkeys) *continued.*

Callithricidæ.

Leontocebus	Tamarins	S. America
Mystax	,,	,,
Ceneocebus	,,	,,
Œdipomidas	Marmosets	C. America
Mico	,,	S. America
Callithrix	,,	,,

The generic name used by these authors for the Langurs is *Pygathrix* (not *Semnopithecus*); *Macaca* refers only to the Barbary ape; *Silenus* is the valid generic name for the macaques. The common macaque is therefore *Silenus rhesus* and the oriental monkey often called *Cynomolgus irus*, from which a number of parasites have been described, is *S. irus*. *Pygathrix* and *Silenus* are oriental forms and *Papio*, *Cercocebus* and *Cercopithecus* African forms.

Knowledge regarding the plasmodial parasites of monkeys was also until recently in a very confused state, so that little could have been said regarding type of parasite in the different genera or their distribution. The revision of Oriental and African plasmodia of monkeys recently published by Sinton and Mulligan, 1933 [7] has, however, made the nature of the different parasites encountered in monkeys much clearer and one can also form tentative conceptions regarding their distribution. Excluding parasites of the great apes which will be referred to later, the following are valid named species and varieties of plasmodial parasites described from monkeys as given by the above authors.

Plasmodium kochi	Cercocebus (?)	Africa
var. bouilliezi	Cercopithecus	,,
var. joyeuxi	,,	,,
var. macfiei	Papio, Cercopithecus	,,
Plasmodium inui	Silenus	Oriental
var. cynomolgi	,,	,,
var. gonderi	Cercocebus	Africa
Plasmodium knowlesi	Silenus	Oriental
Plasmodium semnopitheci	Pygathrix	,,
Plasmodium brazilianum	Cacajao (Brachyurus)	S. America

Forms resembling *P. vivax* and *P. malariæ* are also described in *Ateles* respectively in Central America, by Clark, 1930 [8].

In the main the Oriental and African forms are distinct. Var. *gonderi* is, however, African, though it is classed as a variety of *P. inui*.

It will be well at this point both for the better understanding of the distribution of monkey malaria and later for the appreciation of points connected with the malaria parasites of man and the higher apes to outline briefly some features in the distribution of animals which have a bearing on the question we are now dealing with viz. from whence did man obtain his malaria parasites.

As is well known, animal life on the globe is distributed mainly in accordance with certain great faunal realms or regions, often with very well-defined boundaries within which all forms of life have a certain facies, species, genera, or even higher divisions, being peculiar to them. These realms are: the Australasian, the Neotropical, the Ethiopian, the Oriental, the Palæarctic and Holarctic, and a so-called Transitional, or Mediterranean, realm, which though generally treated as a subregion of the Palæarctic, may in certain groups, e.g. in Anopheles, appear as a rather important and distinct primary subdivision.

That these realms are to a large extent palimpsests of past geological phases appears certain. Thus the Australasian region appears to have been isolated before the placentate mammals reached the region. The strange South American

or Neo-tropical region is the result of isolation from the Eocene to the Pleistocene.

In regard to the areas we are most interested in to-night it may be said that in the Upper Miocene a fauna, characterized by such forms as the tapir, stretched from Spain in Europe far to the east, where in the Malayan region at the present day its features are traceable. Following upon this in the Lower Pliocene a great development of mammalian forms took place in Eastern Europe and Western Asia, forming a fauna whose features at the present time are evident in the existing African fauna. This fauna is represented in the great fossil beds of the Siwaliks in India and extended into China and the East where it has left a mark in some of the features of the recent fauna. In the Pleistocene a slow recession of the Pliocene fauna took place with the advancement of Palæarctic forms leading to the existing arrangement. That the replacement was very slow is shown by many facts, as for example that the hippopotamus was still present in the Pleistocene in Germany, and that the lion and the hyena were driven out of Europe by man.

As we have seen the Old World monkeys first occur in the Miocene of Europe to which continent they are supposed to have come from Africa (Zittel, loc. cit.) They later form a prominent element in the Pliocene fauna, fossil forms much resembling those of the present day being found in Europe, India, etc.

Though there is a general resemblance between the parasites of monkey malaria and human malaria, as there is, it may be well to remember, between those of bird malaria and human malaria, yet the characteristic *P. falciparum* type has not yet been recorded from any monkey. Probably the parasites of monkeys are not really very close to those of man.[1]

Malaria parasites of apes.—The apes first appear in the Oligocene and fossil remains apparently ancestral to the gorilla and chimpanzee occur in the Pliocene in Europe and India. At the present-day apes are represented in the East by the gibbons and the ourang-utan and in Africa by the chimpanzee and two species of gorilla.

A number of observations have been made on malaria parasites in these animals. Halberstaedter and Prowazek, 1907 [10], record a parasite named by them *P. pitheci* from the ourang-utan in Borneo. Other writers have confirmed this for other areas. From the description and figures available there seems at least a possibility that crescentic forms occur. Reichenow, 1920 [11], in the Cameroons describes *P. vivax* and *P. falciparum* in the gorilla and all three forms of human malaria parasites in chimpanzees. Blacklock and Adler, 1922 [12], in Sierra Leone found in a chimpanzee a parasite indistinguishable morphologically from *P. falciparum* and also transient infection with *P. vivax*- and *P. malaria*-like forms. As, however, they failed to infect two Europeans with the blood from the chimpanzee they considered the parasite to be distinct from the human form and named it *P. reichenowi*. Adler, 1923 [13] examined thirteen chimpanzees caught in Sierra Leone and found two infected with parasites indistinguishable from *P. falciparum*, in both cases crescents being present. That these parasites are not due merely to chimpanzees contracting human malaria appears evident from the difficulty with which the animals can be infected, if at all, with human malaria experimentally.

1 All attempts to infect the lower monkeys with human malaria have failed. The only successful transmission to any lower animal is the transient infection with *P. vivax* in the chimpanzee described by Roubaud (loc. cit.). Injection of blood containing monkey parasites (? *P. knowlesi*) into three human volunteers by Knowles and Das Gupta gave rise to a mild, medium and severe infection respectively. Clark 1931 [9] failed with blood and infected mosquitoes to infect human volunteers with monkey infections found by him. Owing to some resemblance between *P. knowlesi* and *P. ovale* I injected at Col. S. P. James's suggestion a monkey (*S. rhesus*) on two occasions with human blood containing *P. ovale*. Though on the second occasion parasites were in very large numbers no infection resulted. The monkey, however, later readily contracted infection with *P. knowlesi* when this parasite was injected.

Mesnil and Roubaud, 1920 [14], attempted to infect chimpanzees by intravenous inoculation with *P. vivax* and *P. falciparum*. They obtained a transient infection in one case with *P. vivax* but in no case any result with *P. falciparum*. They also failed to infect by the bite of infected mosquitoes with *P. falciparum* sporozoites in the glands. Blacklock and Adler, 1924 [15], injected 3 c.c. of human blood with numerous *P. falciparum* into a young chimpanzee but without result.

In the natural infection of apes we find for the first time a close similarity to the parasites of human malaria with the presence of crescentic gametocytes. It is in the ape stem, which is distinct from the other monkeys as far back as the Oligocene (*Propliopithecus*), that one finds for the first time really suggestive evidence of the origin of man's red-cell parasites. It is interesting to note that not only are *P. falciparum*-like parasites present, but that in the chimpanzee three forms very like those of man occur.

The malaria parasites of man.—Early forms of man (*Pithecanthropus, Eoanthropus, Sinanthropus*), appear first in the Pleistocene or at the earliest in late Pliocene. Such forms have been found in very widely separated localities, Java, England, China, etc. Modern man (*Homo sapiens*), though distributed throughout the whole earth, appears to be of Palæarctic origin. True Australasian, Neotropical or Oriental man, in the sense we have been using these terms, almost certainly does not exist. Whether the negro race may be regarded as in any way representing Ethiopian man in this sense is perhaps more uncertain.

To an even greater extent than man himself the distribution of his malaria parasites gives little or no indication of any ordinary zoogeographical relationship. The three common parasites, *P. vivax*, *P. malariæ* and *P. falciparum* appear now to have an almost world-wide distribution, limited only by the existence of temperatures suitable to their transmission by the intermediate host. According to Knowles and Senior White, 1930 [16], the limits of distribution of *P. vivax* are determined by the July isotherm in the northern hemisphere of 60° F. and that of *P. falciparum* by the July isotherm of 70° F. In the southern hemisphere a somewhat similar relation holds good to the January isotherm.

Quartan according to Knowles and Senior White has a peculiar distribution. Though limited as a dominant parasite by the same isotherm as *P. falciparum* its distribution is spotty and shows a tendency to follow a zone of high humidity. It occurs according to them especially in forest regions, islands in the tropics and seashores of subtropical climates and is especially associated with aboriginal inhabitants of countries and areas of high endemicity. They regard this as an older parasite than the other two parasites of man and one that is dying out, *P. falciparum* being the most recently acquired and *P. vivax* holding an intermediate position.

Even with quartan, however, it would seem that the distribution is determined by considerations quite other than those ordinarily determining the distribution of forms of animal life. Though its frequency may be greater in some conditions than others its occurrence is almost if not quite as widespread as the other two parasites. As claimed by Knowles and Senior White it is usually most conspicuous in areas of high endemicity, and hence perhaps as a result in aboriginal tribes and intense foci generally. It is in my experience usually especially conspicuous where owing to temporary drought, etc., other parasites in an intense focus have become reduced in number. Hence it appears to be a parasite with a greater tenacity of hold than the other parasites, at least in untreated communities. Recently Mer, 1934 [17], has found the cycle of development of quartan in the mosquito to be extraordinarily slow, a feature which, combined with its resistance to natural eradication from its host, may account for some of the peculiarities in its distribution.

Whilst, however, the known distribution of these three common malaria parasites of man has not yielded so much information as we might have expected, there is little doubt that the final word has not been said and the possibility of much more emerging when we have learnt better how to distinguish differences in parasites must not be overlooked.

In 1914 Professor J. W. W. Stephens [18] described a peculiar parasite from India which from its very amœboid form he named *P. tenue.* Sinton, 1922 [19] later gave further information about this parasite and showed that the peculiar amœboid form was not its only or its most important point of distinction. Working among aboriginal tribes in the jungly Singhboum tract I considered in a report made by me at that time (Christophers, 1925 [20]) that the parasite I was dealing with was largely, if not almost entirely, *P. tenue.* The more complete establishment of the validity of this species and, if its validity and means of identification is established, its distribution, have still to be worked out.

In 1922 Professor Stephens [21] described another new malaria parasite of man from East Africa which he named *P. ovale.* The validity of this has been shown recently beyond all doubt by the researches of James, Nicol and Shute, 1932 [22], and we can now await with some confidence the working out of its distribution. Is this species confined to Africa? If so it would be a point of very great interest.

This paper is perhaps already overcharged with hypothesis and I rather hesitate to introduce anything further of this nature. The absence of crescent forms in monkeys and their presence in the great apes and man is, however, a very striking fact, the implications of which are very far reaching. In the first case, of course it gives support to the view that the great apes and man constitute a rather independent evolutionary stem, as indeed its geological record shows. Further, it is very suggestive of Africa as the possible original home of malaria. Even if dissemination of the malaria parasites throughout the world was not merely the result of spread from Africa through the movements of modern man, it is still a possible hypothesis that malaria arose in Palæarctic man when he impinged on the fringe of the Pliocene African fauna and acquired the parasites of older types of man ancestrally associated with the great apes.

A theory may be useful even if not true if it stimulates the acquisition of facts. What has been said does suggest the value of certain information at least. We want to know more about the parasites of the orang-utan and the gibbons. Also whether there exist peculiar parasites in indigenous races of such isolated regions as New Guinea. Again, historically, more might perhaps be ascertained as to how malaria reached America. It is a long way and very far north for spread from Asia. When was malaria first known in the United States and under what circumstances? Was it known before the importation of negroes from Africa? Was it known in South America when this continent was first reached from the west? It might be possible to ascertain by historical research some facts of this nature and any results obtained would have a considerable interest.

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