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THE EFFICIENT PARASITE[1]

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THE paper I was supposed to read, but did not, in Section V of this congress bore the title, "The Efficient Parasite." I am going to tell you of a highly efficient parasite I came across in the bush-country of Dutch Guiana. But before coming to that, let me first explain to you what I understand by the word "parasite." Once I have made that clear, the other word, "efficient," will need no explanation.

Now, I beg of you, keep this in mind, that I am not going to tell you what a parasite is, but only what I understand this word to signify. It is simply a matter of definition. Many, or all, of you may have an entirely different definition in mind. So all I ask of you is to accept my definition just for argument's sake and for a period of forty minutes. By the end of that time you may reject it without giving it another thought.

[1] Address delivered before the General Sessions of the Third International Congress for Microbiology, New York, September 2–9, 1939.

Well, then, by parasite I understand an organism wholly dependent on another living organism for its food, its shelter and its reproduction. That other living organism, which provides the parasite with board and lodging, including sufficient shelter to carry on its love affairs without awkward disturbances of any kind, is usually called "the host." If the host is to be of any use to the parasite, it ought to be a living host; a dead host is no good. Now, please, keep that in mind: a dead host is not a host any longer. When the host dies, the whole brood of parasites inside or on his body dies with him. I need not give you any examples; you all have them at your fingers' ends.

Now I ought to admit at once that this statement is not always true. A very striking example is offered by the anthrax bacillus. That is an organism which actually thrives on the death of its host. In fact, it could not continue its existence without that death. It

has to kill its victim, otherwise it itself will perish. To this I answer that the anthrax bacillus is not a parasite at all, because it is a free-living organism, staying in the soil for any number of years, the only peculiarity about it being its non-feeding and non-reproducing. Once in a while, maybe at intervals of many years, it indulges in an orgy of feeding and reproducing. In order to do so it needs a host, better call it a victim or a prey. For it is no more a host than the man who is devoured by a lion. The lion lives by the man's death. The anthrax bacillus lives by the cow's death. For if the cow does not die, but recovers, all the bacilli in its body are killed. But the cow's death stimulates the bacilli to produce spores, a thing they did not do when the cow was still alive. These spores, the free-living stage in the anthrax bacillus' life-cycle, enable it to continue to live in the soil, long after its victim's body has been turned into dust.—No, the anthrax bacillus is not a parasite at all, its victim is not its host, but its prey; this bacillus is a *predaceous organism.* There are many predaceous organisms amongst the bacteria, although not in such a striking fashion as the anthrax bacillus. In fact, it is my opinion that bacteria have done a god deal in the way of blurring our conception of what a parasite really is like.

And, in case you think it is all nonsense that I am trying to make you swallow, let me tell you that this bright idea of mine is not mine at all, but that of your great countryman, Theobald Smith, who has invented the conception, and coined the name, of predaceous organisms, as distinct from true parasites.

So I repeat and maintain that the true parasite is dependent for its existence on the life of its host—more than that, on the well-being of its host. And the efficient parasite is the one which has succeeded in keeping well out of harm's way, harm to its host as well as to itself. The efficient parasite lives quietly in a secluded corner. It is frugal and modest in its feeding and in its reproduction. In short, the efficient parasite is a non-pathogenic organism. Such organisms have sometimes been given separate names: symbionts, if they were supposed to benefit the host; commensals, if they were supposed to do him neither harm nor good. All these names are quite superfluous; "efficient parasite" covers them all.

But are there inefficient parasites? Oh, yes, there are. Every efficient parasite may become an inefficient one, by change of surroundings. And the principal and most distressing sign of its inefficiency (both to itself and to its host) is its pathogenicity. I know it will be rather hard for the medical profession to admit this. But if one reflects that, as a broad rule, nobody thinks of looking for parasites in man, unless there is some incentive to take that trouble, *i.e.,* unless some state of ill health does exist, it is not to be wondered at that the conception of "presence of parasites" and the conception of "disease" are inextricably mixed up. So much so, indeed, that the word "infection" (which really means nothing but the presence of parasites in the host's body) is used as a synonym of "disease." The expression "he is suffering from a malarial infection" may either mean that he is suffering from a fever, or that he is simply showing parasites in his blood, the suffering being usually taken on trust.

That is the reason why parasites, as far as human parasites go, are best known in their inefficient state of pathogenicity. It is different in animals, but the study of parasites in animals offers the disadvantage that we are often unable to decide whether the parasite is doing any harm or not. It is impossible to determine the general mortality, the infant mortality, the natality and other vital statistics in a natural population of earthworms or centipedes.

But to return to the efficient and inefficient parasites. There are parasites which are always (or nearly always) efficient, always harmless, like that dweller of our intestinal tract, *Entamoeba coli.* Whether or not there exist true parasites which have found it possible to carry on hampered by an ineradicable habit of killing their host I do not know and am inclined to doubt. But there can be no doubt that there exist parasites which are so pathogenic that they can only save the existence of their species by some contrivance which constantly enables them to jump from one dying victim to a still healthy one, each time, of course, at the loss of thousands of unfortunate individuals which did not succeed in effecting this transition. But even among these apparent incurables, one sometimes comes across specimens which frankly show for once their true parasitic (*i.e.,* non-pathogenic) nature.

I want to tell you of such a find.

Imagine for a moment a medical man, practicing in a malarious area and invariably in the habit of taking bloodslides of all his fever-patients. (In my country such a practitioner is far from common, but that, no doubt, is different here.) You will agree that such a man will be apt to associate any morbid symptoms he detects in his patients with the parasites he finds in their blood. And, as a rule, he will be proved in the right, by the symptoms disappearing in the course of an anti-malarial treatment. Of course I realize that this, sometimes, is a proof of very doubtful value, but let us leave it at that. But this year I visited a country where the otherwise highly laudable practice of making a bloodslide of every patient would lead to the most complete and hopeless confusion and ill-treatment.

But allow me to relate my experience in the proper order of events. Just as an introduction, let me tell you that I stayed in Dutch Guiana for four months in order to study the sanitary possibilities for the settlement of Jews in that part of the wet tropics. I

soon realized that a proper selection of the site for a prospective settlement would have to take account of malaria as one of the major health problems. I do not want to bother you with the various problems I had to face. Sufficient to say that the study of one of these problems carried me to the densely wooded interior of Dutch Guiana. This interior is not inhabited by European or by the colored agricultural population living in the area nearer the coast. There exist no roads leading to those districts and the rivers, which in the coastal country are the great arteries of traffic, are of no use as a means of transport, since they can not be navigated by any craft except the small native boats or *coryals,* owing to the numerous rapids. In these remote areas a purely African population is living, supposed to have been descended from runaway slaves who settled there in the course of the eighteenth century. They are known as bush Negroes. They are entirely different from the Negro population living in the coastal districts. Except on formal occasion they go almost naked, their houses are different, their language is different. Still they are not quite unaffected by European influence, since the Moravian Brothers and the Roman Catholic Church have established a few mission stations along the upper reaches of the Surinam River. Although these missionary efforts have but little influenced their mode of life, they have, in one village at least, which has been completely Christianized, brought about a very accurate registration of the total population, which has been continued for many years. Every individual is registered at birth, again at the time of christening, of marriage and of death. Since there exists little or no intercourse with the outer world, and since the preachers and schoolmasters living among them know every inhabitant by name, this registration of births and deaths may be regarded as fairly reliable, much more reliable than any data I have been able to collect in other parts of the world under more or less similar circumstances.

The areas inhabited by bush Negroes are all known as highly malarious. Malaria exists extensively in Dutch Guiana, along the coast as well as in the interior. But whereas sub-tertian is comparatively rare in the former districts, it is the predominant type of malaria in the bush, often associated with black-water fever. The reason why the unhealthiness of the bush area has become a byword in the colony is not that the bush Negroes themselves are known to suffer severely. The people who suffer are those habitually living in the coastal districts and who penetrate into the interior for the sake of collecting wood, balata or gold. That is the reason why the localities known to be most unhealthy are invariably those where strangers to the bush country assemble in the largest numbers. It is always cases of malaria among police constables, district commissioners and their staff, balata-bleeders or gold-washers, that come to our notice. The bush Negro looms largely in the background, but he is never mentioned specifically. The bush Negro is supposed to be immune to malaria and, according to classical conceptions, to have acquired this immunity by heavy and prolonged attacks from which he suffered in his infancy and to which many of his less fortunate brothers have succumbed; an immunity gained at the price of a heavy mortality, especially infant mortality.

The village to which my attention was directed by the existence of a registration coming as near to vital statistics as could ever be expected in these wild surroundings, did not suffer from such a bad reputation for the simple reason that there were not sufficient strangers to give the place a bad name. Still it richly deserved that name, for all missionary servants who had not previously lived in a malarious area came down with fever after a period of residence ranging from half a month to three months. My own experience corroborates theirs. I had falciparum malaria eleven days after stopping quinine prophylaxis which I had practiced during my stay in the bush.

Among the bush Negroes themselves, malarial fever was of comparatively rare occurrence. During our ten days' stay in the village my assistant, Dr. van der Kuyp, treated nearly 600 people, two thirds of the whole population, which numbers about 900. Out of these, fourteen were treated for malarial complaints, *i.e.,* a little over 2 per cent. of the total number of patients. You will realize how small that number is, when I tell you that it equals the percentage of cases treated for malaria among the patients in that particular district of the coastal area we have selected as the most appropriate spot for Jewish immigration, since the spleenrate among school children hardly exceeds 10 per cent. So, according to that ten days' medical treatment of the greater part of the bush Negro population of that particular village, malaria was of very little importance.

Malariometric examination of about half of the population had an entirely different tale to tell. I feel I must apologize that I did not examine more in this ideal field of research. But when it came to taking bloodslides of adults, toddlers and infants (there was no difficulty in school children), it took a Sunday morning's sermon on the vice of ingratitude in general and the ingratitude of the bush Negroes in particular, and the most direful threats of never getting any more medicine, to induce them to be examined by me.

The result of this examination comprising about 400 people was, by itself, in no way astonishing. It was identical with that which has been found by others, and by myself, among certain groups of Negroes in Africa. Without encumbering you with too many figures, I may say that the spleenrate of infants and

toddlers was well over 80 per cent. It sank to 75 per cent. in younger school children, to 50 per cent. in older school children and, finally, to 15 per cent. in adults, *i.e.*, people of sixteen years and over. The spleenrate, which in Europeans and Asiatics is such a reliable gauge of malarial conditions, proved wholly inadequate to evaluate the extent of malarial infection in this village. For whereas no more than two fifths of the toddlers and three quarters of the younger school children showed splenic enlargement, nearly all of them had parasites in their blood in numbers sufficient to be detected by a three minutes' search of a thick film. The older school children whose spleen showed palpable enlargement in no more than half of the cases had parasites in their blood in three quarters of the lot, and about one third of the adults were infected, although less than one sixth of them showed splenic enlargement. The infants were the only ones to sustain the honor of the spleenrate as a reliable malariometric figure. Their spleenrate almost reached 90 per cent., their parasite rate 80 per cent. only.

All this, I repeat, is nothing new. Similar high figures have been found in other Negro populations. I may point your attention, however, to the fact that they are rare among Asiatic populations, as has been pointed out by Schüffner. In highly permanently malarious areas of the Dutch East Indies, for instance, the spleenrate in school children and adults maintains the high level which it reached in toddlers, but the parasite rate never attains to the tremendously high levels we see in heavily and permanently infected Negro populations. Moreover, it drops to a very low level in adults.

The figures I quoted, however, claim especial interest if we remember that this was the same population which, at the time of the examination, was paid an unwonted visit by a medical man whose open-air surgery was crowded every day for ten days, to whom people came for all manner of complaints from which they, their children, their toddlers, their infants were suffering. And from that population, with all its eagerness for treatment, we did not succeed in collecting more than a paltry fourteen fever-patients.

Of course, it might be objected that the statement of three fourths of the infants and nearly all the toddlers and younger school children being infected with malaria parasites does not greatly impress one so long as one does not know how many parasites they were carrying at the time of examination. It is all very well to say that these children apparently were in excellent health, although they were parasite carriers. But if "being a parasite carrier" simply means that a few parasites were found after three minutes' search, it is not so difficult to believe that they were not actually ill at the time of examination. To meet this objection let me tell you that about four fifths of the infants and the toddlers carrying parasites had at least one parasite for every ten leucocytes, a number amply sufficient to render any man of, say, my stamp thoroughly miserable, all the more so since the majority of infections are falciparum. But those brats did not care a bit!

No, they did not care a bit within that period of ten days. But that is only a snapshot. But how did they fare later on? I can not tell you. But I can tell you how they fared earlier in the year and in the preceding years. And since this year was in no way abnormal, from a health point of view (as the local European nurse, stationed there for over four years, assured us), we may assume that malaria infection was normal too. Well, in the year preceding our investigation, the general mortality in that bush Negro village was 16 per thousand, the natality 34 per thousand and the infant mortality 71 per thousand infants born alive. Over the last twelve years (from 1927–1938) the general mortality was 21 per thousand and the infant mortality 107 per thousand. These are figures which would not show well in a proud American city or, if I may say so with some satisfaction, in a town like Amsterdam. But even as late as 1919 infant mortality over the whole of the Netherlands ranged still over 90 per thousand. So we may conclude that high and constant malarial infection to which these bush Negroes are subjected not only leaves the adults unaffected but does little harm even to the youngest children. At any rate, we are in that village far away from that condition of immunity in adults, described to be attained over the corpses of thousands of young children. Allow me to repeat that this description is absolutely correct. Such conditions do exist. But not among these bush Negroes.

And how to return to the point from which I started —the efficient parasite. I suppose you have, by now, gathered what I mean by this word. Plasmodium falciparum, vivax, malariae, they all are efficient parasites in the collective bodies of that bush Negro population. Certainly things did not proceed as smoothly as might have been expected from ideally efficient parasites. There is some struggle, as exemplified by the splenic reaction in children, which even in adults has not quite subsided. And the heavy drop in the number of parasites per carrier (in adult carriers more than nine tenths have less than one parasite per 10 leucocytes) also shows that the parasites pay for the benefit of continuing in the adult human host by strictly enforced birth control. All the same, compared with the interaction of the parasite and the white human host, we may safely conclude that the parasites in the bush Negroes are fairly efficient and that there is little likelihood of extinction of either species, man or plasmodium.

But what one may well ask is this. Who deserves

the epithet "efficient"—the parasite or the host? Had not the title of the paper better be "The Efficient Host"? In this case this is undoubtedly true. These same parasites which behaved in such an exemplary manner in the bush Negro's body, behaved very badly in my own. It is the bush Negro's body which, first by refusing to be killed, and afterwards by a judicious and not too far carried reduction of the number of parasites, finally obtains that nicely adjusted equilibrium which does not even require the intervention of the spleen. Nevertheless, I maintain the parasite's claim to the title of "efficient" since it allows itself to be domesticated in this way.

So we come to this conclusion. If we see a parasite behaving as it should behave—not harming its host and, as a consequence, not harming itself—in short, if we see it behaving as an efficient parasite, we know that this is the outcome of an interaction between host and parasite of a struggle in which both have had to sacrifice something. The host has had to get rid of his over-sensitiveness, he has had to become tolerant of the parasite's presence in his body. And the parasite has had to suffer a considerable reduction in its procreative powers. It is an adaptation of the host to a greatly subdued parasite. The Negro body, better than the body of most human beings, seems extraordinarily well fitted to pass unscathed through the various stages of this adaptation.

And now, finally, you will allow me to say something on the subject which I have had in mind these last five months: the settlement of political refugees in the tropics, more especially in the Guianas. It has little to do with the efficient parasite but a great deal with the propensity of the African race to act as a highly efficient host of the malaria parasites.

Up till now the importance of this peculiarity of the African race has been underrated because many of the greatest authorities have refused to regard it as a racial quality by which the African races fundamentally differ from other races. Every race can acquire some measure of immunity to malaria. The African race, together with a few obscure hill-tribes in India, are the only ones to be born with it.

I need hardly emphasize that this racial quality affords the Africans a considerable advantage over the other races in the case of the interracial struggle for existence developing in an environment in which malaria plays an important part. I am not going to enlarge on this subject which would completely carry me away from the beaten track I am following. To those who wish to reflect on this remark of mine, I would recommend the perusal of Grenfell Price's book on "White Settlement in the Tropics," recently issued by the American Geographical Society. Notably, his remarks on the fate of the white race in some parts of the tropical world are worth reading in this connection.

But this I would say. Any attempt at settlement of whites in areas where malaria is rife and where, by the conditions under which the settlement is organized they will have to compete with the African race on a footing approaching equality, is bound to be a cruel failure unless malaria has been reduced to insignificance before the settlement is started or unless an enforced segregation is rigorously applied to keep the two races so much apart that there can be no longer any competition between the two.

I realize that my address has been somewhat out of tune with the highly cultured scientific sphere of this congress, where the serene atmosphere of the laboratory and the lecture room prevails. I came here directly from the wilds. The field has been my laboratory for months and I have consorted more with bush Negroes and Indians than with cultured people. Moreover, I can not get rid at a moment's notice of the ideas and interests which have occupied my mind since I left Holland and which, although of little importance in the present circumstances, are bound to clamor for notice at some future date. Accept my address as a contribution to the vexed question of the host-parasite relationship. That I did not quite succeed at the end in keeping away from the subject I have very much at heart must be regarded as an amiable mental aberration comparable with that from which one of Charles Dickens's famous characters of fiction suffered when he never succeeded in keeping King Charles' head out of the Memorial he was writing. If I had had Mr. Dick's unlimited time at my disposal I would have torn up this memorial to write another one. Since I had not the time, I had to offer it to you as it is.

THE KINETICS OF CONTACT CATALYSTS AND THE INDUSTRIAL BACKGROUND[1]

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IT is a tragedy of the efforts of the student of chemical reactions at surfaces, in these closing decades of the two centuries of service to culture and civilization that the University of Pennsylvania is now celebrating, that the finest flowers of the effort should have synchronized with and been made subservient to the inter-

[1] Read at the Bicentennial Conference of the University of Pennsylvania, September 17, 1940.