MALARIA TERMINOLOGY

Report of a Drafting Committee Appointed by the
World Health Organization
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WORLD HEALTH ORGANIZATION
PALAIS DES NATIONS
GENEVA

1953
NOTE

Authors alone are responsible for views expressed in the Monograph Series of the World Health Organization

A report on French malaria terminology is being prepared for publication in Organisation mondiale de la Santé : Série de Monographies.
## CONTENTS

<table>
<thead>
<tr>
<th>Introduction</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>PART I. COMMENTARY</td>
<td>9</td>
</tr>
<tr>
<td>Chapter 1. The malaria parasites and the infections to which they give rise</td>
<td>11</td>
</tr>
<tr>
<td>The name malaria</td>
<td>11</td>
</tr>
<tr>
<td>The malaria parasites</td>
<td>11</td>
</tr>
<tr>
<td>Terms relating to forms of the parasite in the vertebrate host</td>
<td>15</td>
</tr>
<tr>
<td>Terms relating to the structure of the parasite, and to the changes it produces in, and its relation to, the red cell</td>
<td>19</td>
</tr>
<tr>
<td>Terms relating to forms of the parasite in the invertebrate host</td>
<td>20</td>
</tr>
<tr>
<td>Terms used in the description of the nature and course of infection</td>
<td>20</td>
</tr>
<tr>
<td>Chapter 2. Malaria in the human community</td>
<td>27</td>
</tr>
<tr>
<td>Terms applied to types of prevalence and intensity of malaria in the human community</td>
<td>27</td>
</tr>
<tr>
<td>Measurement of malaria; general</td>
<td>29</td>
</tr>
<tr>
<td>Terms used in measurement of malaria by examination of the blood</td>
<td>31</td>
</tr>
<tr>
<td>Terms used in measurement of malaria according to enlargement of the spleen</td>
<td>35</td>
</tr>
<tr>
<td>Indices of endemicity</td>
<td>39</td>
</tr>
<tr>
<td>Chapter 3. Terms applied to the vector</td>
<td>42</td>
</tr>
<tr>
<td>The name anopheles</td>
<td>42</td>
</tr>
<tr>
<td>Species and varieties of anopheles</td>
<td>42</td>
</tr>
<tr>
<td>Stages of growth and development</td>
<td>42</td>
</tr>
<tr>
<td>Life history and behaviour</td>
<td>44</td>
</tr>
<tr>
<td>The anopheles community</td>
<td>47</td>
</tr>
<tr>
<td>Infection in the anopheles community</td>
<td>47</td>
</tr>
<tr>
<td>Terms applied to methods of control directed against the vector</td>
<td>48</td>
</tr>
<tr>
<td>PART II. GLOSSARY</td>
<td>49</td>
</tr>
<tr>
<td>References</td>
<td>81</td>
</tr>
</tbody>
</table>
FIGURES

1. Exoerythrocytic schizogony: Type I — *elongatum* ................................. 16
2. Exoerythrocytic schizogony: Type II — *gallinaceum* ................................. 16
3. Exoerythrocytic schizogony: Type III — *mexicanum* .............................. 17
4. Exoerythrocytic schizogony: Type IV — *cynomolgi* ............................... 17
5. Exoerythrocytic schizogony: Type V — *falciparum* ............................... 17
6. Exoerythrocytic schizogony: Type VI — *murinum* ................................. 17
7. Exoerythrocytic schizogony: Type VII — *kochi* ................................. 17
8. Schema for recording splenomegaly data ............................................. 37
INTRODUCTION

At its third session held in Geneva in August 1949, the Expert Committee on Malaria of the World Health Organization expressed the opinion that the methods used in the conduct of epidemiological malaria inquiries needed standardization, and recommended the appointment of a drafting committee to study the question. It was thought that the object desired could best be achieved by a revision of the Report on terminology in malaria\textsuperscript{19},* published in 1940 by the Malaria Commission of the League of Nations, and now out of print.

In accordance with this recommendation, a drafting committee was appointed, with the following members: Major-General Sir Gordon Covell, Dr. P. F. Russell, and Professor N. H. Swellengrebel (Chairman).

The drafting committee commenced its task by studying the admirable Report cited above. It was decided that revision should proceed on the following lines:

(1) incorporation of the notable contributions which have been made to knowledge of the subject during the intervening twelve years;

(2) redistribution of the emphasis on certain subjects in the light of these contributions;

(3) development of certain sections to give an authoritative ruling on issues which were then in doubt;

(4) re-interpretation of certain points.

The first session of the drafting committee was limited to two days in Kampala, Uganda, at the time when the Malaria Conference in Equatorial Africa met in that town. The Expert Committee on Malaria of the World Health Organization at its fourth session, held after the conclusion of the conference, instructed the drafting committee to meet again at a later date to complete its work. No attempt was to be made to draft the report in English and French, as had been done in the first issue. A separate drafting committee, under the chairmanship of Médecin-Général Vaucel, was to be responsible for the French report.

Acting on these instructions, the drafting committee met again from 13 to 18 August 1951, this time in Amsterdam, where they were joined

\textsuperscript{*} Produced by a Subcommittee of the Malaria Commission, the members of which were as follows: Sir Rickard Christophers (author of the draft report), Dr. L. W. Hackett, Dr. E. J. Pampana (Secretary to the Malaria Commission), Professor W. A. P. Schüffner, and Professor Edmond Sergent.
by Dr. P. Bertagna, representing the Malaria Section of the World Health Organization, and where they completed their task.

In accordance with the procedure adopted in the first edition, terms for engineering techniques used in malaria control have not been included, because they are not specifically related to malaria. With regard to certain biological terms coming under the same heading, the drafting committee has sometimes been in doubt as to their inclusion. No uniform course has been adopted; each doubtful case has been dealt with on its own merits.

Since the Expert Committee on Insecticides of the World Health Organization has prepared a glossary of terms on spraying apparatus, and since a list of modern antimalarial drugs is being prepared by a small group of the Expert Panel on Malaria, the drafting committee has excluded terms relating to these subjects.

The glossary has been simplified (a) by omitting definitions of terms (not the terms themselves) adequately dealt with in the commentary; (b) by abolishing typographical distinctions in the printing of the several terms; (c) by omitting French equivalents of English terms, and English equivalents of French terms not commonly used in English-writing countries. This simplification was justified because a French edition of the Report will be issued separately.

Finally, the drafting committee wishes to acknowledge the invaluable aid received from Sir Rickard Christophers, from Dr. C. Huff and Dr. P. C. C. Garnham in the matter of the tissue stages of plasmodia (the figures illustrating which were kindly supplied by Dr. Garnham), from Dr. D. Bagster Wilson with regard to modern views on collective immunity in malaria, and from Mr. H. S. Leeson, who revised the entomological terms included in the glossary.

** Previously published (with the exception of fig. 3) in a paper by P. C. C. Garnham (Brit. med. Bull. (1951) 8, 10) and reproduced here by kind permission of the editors
Part I

COMMENTARY *

* For index to the Commentary, see Part II: Glossary (page 49).
CHAPTER 1

THE MALARIA PARASITES AND THE INFECTIONS TO WHICH THEY GIVE RISE

The Name Malaria

Two names only are now in general use in scientific writings to designate the condition of infection or disease in man brought about by parasites of the genus Plasmodium—malaria by English, German, and Italian writers, and paludisme or paludismo by French and Spanish writers, respectively. In Portuguese writings, the name sezonismo is sometimes employed.

Although these names are indicative of more or less mistaken conceptions of the true causation of the disease, no urgent question of any more appropriate name appears to arise, although it would be proper to refer to plasmodial infections as plasmodioses.

It is usual to employ the word malaria for "malaria parasite", "malaria mosquito", but to use malarial for "malarial conditions", "malarial infection", "malarial fever".

Certain derivations from the name are commonly used—e.g., malariology, malariologist, malarriometry.

The Malaria Parasites

The organisms causing malaria are commonly referred to collectively as malaria parasites.

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\[a\] The term malaria is also now commonly applied to infection by parasites of the genera Plasmodium in birds (bird malaria, avian malaria) and in monkeys and apes (monkey malaria, ape malaria). Infections of dogs, cattle, or other animals with Babesia, Theileria, etc., are usually termed piroplasmoses, tick fever, etc., but are occasionally referred to, though undesirably, as dog or cattle malaria. So, too, Haemoproteus infection in birds and Hepatozostis infection in monkeys should not be termed malaria.

\[b\] The conception of malaria as a single morbid process or disease, and certainly the use of the term malaria, is of relatively late origin. Torti (1658-1741), who first definitely distinguished malarial from other fevers through the former's property of being cured by cinchona bark, does not employ the term malaria, or indeed any single term synonymous with it, in his famous work Therapeutica specialis, of which the first edition was published in 1712. A reference to the word malaria in general literature is quoted by the Oxford Dictionary as made in regard to the fevers in Rome by Horace Walpole in 1740.

Maccullloch, in his book Malaria (1827) was the first English medical writer to use this name, which he states he borrowed from Italy. The name malaria was first used more in the sense of the condition or conditions responsible for the causation of the miasmatic fevers than as indicating the disease as such. Later, a clinical and eventually a parasitological designation seems to have been the natural course of evolution of the term. Epidemiologically, there is often some return to its use in a general sense as designating a condition not wholly confined to human infection—i.e., as carrying the idea of prevalence of the parasite in man and mosquito in an area.
The zoological nomenclature of the parasites is very confused and has been the subject of a great deal of discussion in the literature. In regard to the generic name, it is now most generally held that only one genus should be used to include all species which prey on man and that, except for *Hepatocystis* and *Haemoproteus*, all the pigmented red cell parasites in man and animals should be included in the same genus, which genus by priority of naming is *Plasmodium* Marchiafava & Celli, 1885. It is therefore undesirable in the face of such opinion to use the generic name *Laverania*.

The position of the specific names, particularly of the malignant tertian parasite, is more complicated. The controversy has been concerned chiefly with the question of whether *praecox*, *immaculatum*, or *falciparum* is the correct name to use. Grassi & Feletti, since they believed that certain parasites (*Proteosoma*) seen by them in birds from a malarious locality were identical with the parasite of "quotidian fever with short intermissions"—that is, with what is now often called the malignant tertian parasite—gave to both these parasites the name *praecox*. Those who hold that the authors gave two species the same name, but later indicated the human parasite as *praecox*, consider this name correct for the malignant tertian parasite. Others, however, hold that the bird parasite was clearly indicated at the first naming so that *praecox* cannot be valid for the human parasite, and that the correct name for this must be dependent on subsequent naming. Those who consider that, as a result of such subsequent naming, the first valid name was *immaculatum* Grassi & Feletti, 1892, use this designation. Others, for various reasons, do not consider *immaculatum* to be valid and employ *falciparum* Welch, 1897, which they consider to be the first name for which validity can be justified.

Actually, the position has been shown to be even more difficult than this, since Laveran's name *malariae* is undoubtedly valid as applied to the malignant tertian parasite, which he clearly described, and the name *malariae* given by Grassi & Feletti to the quartan parasite was not, as assumed by many later writers, intended to displace Laveran's name, but was their own name given to a species in another genus (*Haemamoeba*). In other words, there were two species with the same specific name, but in two different genera—i.e., *Laverania malariae* Laveran, 1881, the malignant tertian parasite, and *Haemamoeba malariae* Grassi & Feletti, 1890, the quartan parasite. Both names are perfectly valid so long as the two

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* Some authors consider it desirable to use *Laverania* for the reason that the crescentic shape of the gametocytes is a good differentiating character. It seems, however, better to accept the more common opinion, at least for the present. For discussion of validity of the name *Plasmodium*, see Christophers & Sinton and Sergeant, Sergent, Parrot & Catanei.

* For a full account of the position in respect of these names, see Sergeant, Sergent & Catanei and also remarks upon *immaculatum* in Christophers & Sinton and Sergeant et al.
genera are maintained. The latter (not the former) specific name, however, becomes invalid when only one genus (*Plasmodium*) is employed, since *Laverania malariae* has priority of naming. Such a view, if accepted, makes *praecox*, *immaculatum*, and *falciparum*, as well as *malariae*, all invalid when applied to the quartan parasite.

In view of the great difficulty in deciding upon the correct specific name by right, and of using such a name if decided upon without now causing intolerable confusion, and for the sake of the practical advantages to be gained by uniformity, the drafting committee advises the adoption of the names as given in the decision (Opinion 104) of the International Commission on Zoological Nomenclature (1928). Such procedure would in no sense be arbitrary or unscientific, since zoologists have agreed to abide by decisions of the International Commission in cases of this kind. This nomenclature is, moreover, that now in most common use.

Accepting the above considerations as to the use of generic and specific names, and excluding all forms the status of which has not been fully established, the following are the zoological names of the known human malaria parasites:

<table>
<thead>
<tr>
<th>Full zoological designation</th>
<th>Abbreviated form in text</th>
</tr>
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<tbody>
<tr>
<td><em>Plasmodium malariae</em> (Laveran), 1881</td>
<td><em>P. malariae</em></td>
</tr>
<tr>
<td><em>Plasmodium vivax</em> (Grassi &amp; Feletti), 1890</td>
<td><em>P. vivax</em></td>
</tr>
<tr>
<td><em>Plasmodium falciparum</em> Welch, 1897</td>
<td><em>P. falciparum</em></td>
</tr>
<tr>
<td><em>Plasmodium ovale</em> Stephens,* 1922</td>
<td><em>P. ovale</em></td>
</tr>
</tbody>
</table>

* *P. tenue* Stephens, 1914, is no longer accepted as a distinct species.

Both the generic and specific names, in accordance with usual zoological procedure, should be given in italics or, if the context demands, in some other distinctive type. The genus should be given with a capital

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* For a complete summary of the position, see Christophers & Sinton and Sergent, Parrot & Cattaneo.

† The relevant parts of the Opinion are as follows:

"Opinion 104.—The following fifty-seven generic names with type species cited are hereby placed on the official list of generic names:

" *Laverania* Grassi and Feletti, 1890a, 60, mt. *malariae* (homonym) so *falciparum* Welch, 1897, 36, 47, type host *Homo*. (For authors who consider the parasite of aestivo-autumnal malaria genetically distinct from that of quartan malaria.) Not *Laverania* Labbé, 1899a, 82, type *ranarium*, type host *Rana esculenta*.

" *Plasmodium* Marchiafava and Celli, 1885d, 791, mt. tsd. *malariae* (as restricted to quartan fever), type host *Homo* . . ."

That *Laverania* is not employed as a genus (on zoological grounds) would not appear to alter at all the citation of the specific name of the malignant tertian parasite as *falciparum*, which, further, is the name at present most widely used. The only possible cause of uncertainty would appear to be whether the Opinion can be regarded as concerned only with the generic names, the correctness of the genotypes not being raised. The answer to such an objection would be to make application for a new decision of the Commission to fix names as at present in general use. The difficulty is not so much to determine the correct name by the laws of priority, which is a matter of careful research, as the impossibility of applying it when found without now causing confusion.
letter, the species with a small initial letter, even though the name be one designating a person or place. A specific name with a capital may, however, be used for a name designating a person or place in botanical nomenclature, e.g., Cinchona Ledgeriana.

The describer’s name and the year of description are also usually set out when giving the formal name of a species, to avoid all ambiguity due to possible synonymy. The describer’s name should follow without punctuation after the specific name, and then, after a comma, the year of description. Round brackets (parentheses) around the describer’s name are used only where zoological procedure requires it—i.e., to indicate that the species was originally described under another generic name. The brackets are therefore correctly given in the case of P. vivax (Grassi & Feletti), since this species was originally described as Haemamoeba vivax, but not in that of P. falciparum Welch, originally named Plasmodium fal- ciparum. The describer’s name and year are not, however, usually repeated except where necessary to avoid ambiguity, and the abbreviated name is all that is generally needed when the full name has once been given in the context. The abbreviated name should not, however, be used in the title of a communication.

The use of Pl. for Plasmodium is unnecessary, as no zoological significance attaches to the abbreviated form, which is merely a convenience. The only requirement is that there should be no ambiguity as to what genus is meant. Pl. may be used, therefore, if it is thought desirable to avoid confusion with another generic name beginning with P, also occurring in the communication, though such a consideration is not likely often to arise.

A number of colloquial names have been applied to the various plasmodia and the infections caused by them, as follows:

<table>
<thead>
<tr>
<th>Name of parasite</th>
<th>Colloquial name</th>
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<tbody>
<tr>
<td>P. vivax</td>
<td>Benign tertian (B.T.)</td>
</tr>
<tr>
<td></td>
<td>Simple tertian</td>
</tr>
<tr>
<td></td>
<td>Tertian</td>
</tr>
<tr>
<td>P. malariae</td>
<td>Quartan</td>
</tr>
<tr>
<td>P. falciparum</td>
<td>Malignant tertian (M.T.)</td>
</tr>
<tr>
<td></td>
<td>Aestivo-autumnal</td>
</tr>
<tr>
<td></td>
<td>Sub tertian</td>
</tr>
<tr>
<td></td>
<td>Malignant</td>
</tr>
<tr>
<td></td>
<td>Tropical, tropica</td>
</tr>
<tr>
<td></td>
<td>Pernicious, perniciosa</td>
</tr>
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</table>

G This is the usual, if not universal, procedure in zoology, but use of a capital for a specific name designating the name of a person does not seem actually to be forbidden in the rules laid down by the International Commission (see Article 13-14).
These colloquial names are becoming obsolete. The drafting committee recommends their replacement by the unitalicized specific names of the plasmodia concerned, e.g., vivax malaria, falciparum parasite, malariae infection, etc.

Terms Relating to Forms of the Parasite in the Vertebrate Host

In the vertebrate host, following inoculation of sporozoites, there is a short period of about half an hour when the blood is infective if inoculated in large quantities. This phase is followed by a period during which no infected erythrocytes can be found and the blood is non-infective. This “prepatent” phase is fairly constant in duration and is followed by a period during which parasites are found in erythrocytes. Clear evidence in certain avian forms of malaria and recent findings in man and monkeys indicate that the malaria parasites are in fixed-tissue cells in the body of the vertebrate host during the prepatent period and that they may persist in these cells during latency (see glossary).

In strict protozoological terminology, all asexual forms with multiple division of nuclei are schizonts and the earlier undivided asexual parasites are trophozoites.

Definitions

Exoerythrocytic stages are those stages of the parasite in the vertebrate host during which it lives in cells other than erythrocytes and reticulocytes. It is necessary to distinguish between those exoerythrocytic stages derived from sporozoites and those capable of arising from erythrocytic stages of the parasite. The term cryptozoic schizont, or better cryptozoite, is applied to those exoerythrocytic stages which arise directly from sporozoites. Subsequent generations occurring before the appearance of parasitaemia are known as metacryptozoic schizonts or better as metacryptozoites. Cryptozoites and metacryptozoites constitute collectively the pre-erythrocytic stages. The exoerythrocytic stages arising in blood-induced infections, or appearing concomitantly with or later than the infection of erythrocytes, are known as phanerozoites.

On the basis chiefly of observations in avian malaria it appears that within the first vertebrate host cell there takes place cryptozoic schizogony with the production of cryptozoites or cryptozoic merozoites arising directly from sporozoites. Cryptozoites on liberation may enter other fixed-tissue

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h Some observers advance the theory that the malaria parasite lies on the outside of the red blood-cell for a part, or the whole, of the erythrocytic stage. In this report the word “in” has been used, but the possibility that the above theory is correct has not been overlooked.

i The correct pronunciation of schizo- is “skidzo”.

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or non-erythrocytic cells, initiating further exoerythrocytic schizogony. The progeny of the second and of succeeding generations after exoerythrocytic schizogony are called metacryptozoites. Some of the metacryptozoites, especially after three or four generations, appear to penetrate erythrocytes to initiate erythrocytic schizogony. The term tissue phase embraces all exoerythrocytic forms, whether pre-erythrocytic or not.

In avian malaria, certain exoerythrocytic schizonts have many nuclei but scanty cytoplasm. These are known as microschizonts and they produce a large number of micromerozoites which in size and structure are like the merozoites resulting from schizogony in the erythrocytes. These micromerozoites are probably destined to enter erythrocytes. There are also produced, from macroschizonts, smaller numbers of macromerozoites, considerably larger than the micromerozoites. It has been suggested that the macromerozoite does not invade red blood-cells.

The course of exoerythrocytic schizogony follows seven principal types (see fig. 1-7). These types are: I, elongatum; II, gallinaceum; III, mexicanum; IV, cynomolgi; V, falciparum; VI, murinum; VII, kochi. The tissue stage, which may represent the primitive form of the parasite, is divided into two phases—pre-erythrocytic or primary exoerythrocytic schizogony, and exoerythrocytic (sensu stricto) or secondary exoerythrocytic schizogony. The former represents the development of the sporozoite, the latter represents subsequent stages which are partly responsible for the continuance of the infection and are the cause of relapses. For the gallinaceum

**FIG. 1. EXOERYTHROCYTIC SCHIZOGONY: TYPE I — ELONGATUM**

![Diagram](image)

**FIG. 2. EXOERYTHROCYTIC SCHIZOGONY: TYPE II — GALLINACEUM**

![Diagram](image)
and *elongatum* types there is two-way traffic between blood and tissue, so that, in these types, tissue stages may arise following blood inoculations; for the *cynomolgi* and *falciparum* types there is a phase from tissue to blood in one direction only, so that, in these types, tissue stages can only follow sporozoite inoculations.

*Elongatum* type occurs in *P. elongatum* of birds. *P. pitmanii* of the African skink and *P. berghei* of the Congo tree-rat show certain affinities with this group, but are not as yet definitely assigned to it.

*Gallinaceum* type is found in *P. gallinaceum, relictum, cathemerium, lophurae, and fallax*, and probably in *circumflexum, durae, nucleophilum*, and *hexamerium*.

*Mexicanum* type has so far been found only in *P. mexicanum*, a parasite of New World lizards.

*Cynomolgi* type has been established for *P. cynomolgi, vivax*, and *inui*. It probably also exists in *P. malariae* of man and the chimpanzee, and in the simian parasites *P. gonderi, schwetzi*, and *brasilianum*. It seems likely that *P. ovale* of man may also belong to this group, though the position of this parasite has not yet been finally determined.

*Falciparum* type includes *P. falciparum* and probably the crescent-producing *P. reichenowi* of the chimpanzee.

*Murinum* type is found in *P. murinum*, a parasite of bats. It is possible that *P. brodeni* of the elephant shrew belongs to this group also.

*Kochi* type includes, besides *Hepatocystis kochi, H. epomophori* of African fruit-bats, *H. vassali* of Malayan squirrels, and the parasites of the Himalayan flying-fox. It is probable that *P. pteropi, taiwanensis*, and *semnopithecii* also belong to this group.

Merozoites are young forms—the direct product of segmentation either of a tissue schizont or of a blood schizont. They may be free or attached to a host cell. Trophozoites are asexual forms in (a) ring stage, and (b) later early amoeboid or solid stages with chromatin as yet undivided in the process of schizogony.1 Schizonts are large asexual forms in which the chromatin shows evidence of schizogonic division. There may be such forms with two, four, or more chromatin masses, but the merozoites have not yet been differentiated. *Mature schizonts* are fully developed schizonts in which merozoites have taken shape. These mature forms are also known as *sporulation forms, segmentation forms, segmenters*, or "*rosettes*".

Since the process here concerned is not that of spore formation, the terms sporulation forms and sporont are objectionable. The terms *segmenters* and *segmenting bodies*, formerly much used, are now less employed,

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1 The presence in some young ring forms of two or more chromatin granules bears no relation to the schizogonic process.
although the maturing of a generation, and liberation of the merozoites, are still commonly referred to as *segmentation*—for example, when indicating the relation of a stage of the parasite to the fever attack.

*Gametocytes* are sexual forms, starting as small solid bodies within a red blood-cell and reaching maturity in the same vertebrate host cell.\(^k\) The male gametocytes are called *microgametocytes* and the females are called *macrogametocytes*. Further changes, *exflagellation* and *maturation* respectively, producing the *microgametes* (flagella) and *macrogametes*, occur, so far as is known, only outside the body of the vertebrate host. Gametocytes (not gametes) is therefore the correct name for such sexual forms in the vertebrate body.

The gametocytes of *P. falciparum* from their characteristic appearance are commonly called *crescents*. It is not uncommon to find the term gametocytes (e.g., in reference to the action of certain drugs) used as if the terms gametocytes and crescents were synonymous. Actually, where crescents are intended, it is better to use either this term or falciparum gametocytes.

Trophozoites usually grow and mature so that relatively large numbers are always at about the same stage of development. Such groups constitute *generations*, one or more of which in different stages of growth may be present at any given time in the host. Commonly, these stages represent generations maturing at approximately the same time on successive days. Such regular development gives rise to the characteristic *periodicity* displayed in the development of many plasmodia. The specific period which each species of parasite takes for the completion of the growth of a generation—i.e., from any given stage to the same stage in the succeeding generation—constitutes the duration of the *schizogonic cycle* or *schizogonic period* of the parasite.

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**Terms Relating to the Structure of the Parasite, and to the Changes it Produces in, and its Relation to, the Red Cell**

Terms relating to the morphology of the parasites are *cytoplasm*, *chromatin* (granules or masses), and *pigment* (grains, granules, or clumps). The nature (i.e., whether nuclear or nutritive) of the "vacuole" seen in the ring forms is still uncertain, so that provisionally the best term would appear to be *vacuole*. Malarial pigment, frequently referred to as *haemozoin*, is now known to be *haematin*. The word *melanin*, formerly used, is incorrect.

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\(^k\) In a microscopical examination of malarial blood, those very young gametocytes, which cannot be distinguished from true trophozoites, are counted as trophozoites.
Among the abnormal appearances brought about by the parasites in the host red cell, the most important are enlargement, decolorization, and certain forms of granulation seen in the stained cell. Of such granulations the most important are the fine even granulations—Schüffner's dots—brought out by the Romanowsky stain in its various forms in vivax, and the coarse, more irregular markings—Maurer's spots or clefts—seen in falciparum-infected cells. Granulation very similar to that in vivax is seen with ovale; another form brought out only by special staining in malariae is called Ziemann's stippling.¹

Among other changes described are the "brassy corpuscles" of early literature seen in fresh preparations with falciparum, and an oval shape of the cell associated with a wavy edge at one or both ends (crenulation or fimbriation) in ovale infection.

Terms Relating to Forms of the Parasite in the Invertebrate Host

On entering the midgut, the gametocytes, male and female, undergo respectively exflagellation and maturation—i.e., the setting-free of the flagella or microgametes and extrusion of polar bodies (?), and other changes by which the macrogametocyte becomes the macrogamete. On fertilization, the macrogamete undergoes further changes, becoming the ookinete (travelling vermicle). The ookinete in turn, after passing through the gut wall, becomes the oocyst. Within the oocyst are developed the sporozoites.

The term zygote (strictly, all the products of sexual union) was formerly applied to designate the oocyst, but such usage is incorrect. Certain more or less apparently distinct subdivisions of the contents of the oocyst were formerly thought to be sporoblasts—a view no longer held.

Terms Used in the Description of the Nature and Course of Infection

Terms used to describe the nature and course of infection may relate to one or other of several different aspects of such infection:

1 the clinical (e.g., malarial fever, malarial attack, malarial cachexia, latent malaria, etc.);

2 the parasitological or immunological (e.g., malarial infection, primary attack, relapse, reinfection, superinfection, etc.);

3 those connected with treatment, prophylaxis, or control.

Clinically, there is an incubation period (see glossary) followed by onset of the primary attack. Even in the absence of any further contraction of

¹ Though it is usual to use the term Maurer's spots for the flecked type of granulation, both types of granulation were originally described by Schüffner, and the second by Stephens & Christopher, before Maurer.
infection, this first attack is frequently followed at intervals by others due to the same original infection. Such subsequent attacks have been variously designated by different authors in relation to their time of occurrence as recrudescences, recurrences, short-term relapses, or relapses. These terms, however, have been employed with such different significance by different authorities that, in the drafting committee's opinion, it would be advisable to use the term relapse for any renewal of clinical activity occurring after an interval from the primary attack greater than that due merely to periodicity. It is desirable, however, to reserve the name long-term relapse for the peculiar relapse occurring in some strains of vivax (and probably ovale) infection after a very long interval (i.e., commonly about nine months subsequent to infection). Attacks not due to the original infection, but resulting from subsequent fresh infection, are reinfections.

By attack in either sense, as used above, is meant a whole period of acute (overt) illness, which frequently consists of a number of separate paroxysms in the sense of short manifestations of malaria. Thus an attack may consist of several or many paroxysms or of a single paroxysm only. It may also, however, consist of a period of irregular high temperature extending over a number of days where the paroxysms are confused or indistinguishable (as often in falciparum malaria or at the first onset of the first vivax infection"'), or of such a period followed by a succession of paroxysms.

Where the paroxysms are distinct with an interval of normal temperature, and follow regularly, the fever may be described as of intermittent type; where the temperature remains high for some days without definite intermissions, it may be described as of remittent type. It is undesirable, however, to use the terms intermittent and remittent in such a way as might be taken to imply (as in the older literature) that these are distinct forms or types of malaria.

The occurrence of a paroxysm normally depends upon the maturation (schizogony) of a generation of parasites. Thus the number of generations present at the time in the blood, and the schizogonic period or cycle of the particular parasite, give rise to clinical periodicity. Such periodicity may take the form of paroxysms on alternate days (tertian periodicity),

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"James's classification of relapses in vivax infection, which has been very generally followed, is given thus:"

"Recrudescence.—A return of fever and parasites at any time within eight weeks after recovery from the primary attack."

"Relapse.—A return of fever and parasites later than eight weeks, but earlier than twenty-four weeks after recovery from the primary attack."

"Recurrence.—A return of fever and parasites later than twenty-four weeks after recovery from the primary attack. This means as a rule later than twenty-six weeks after the date of primary infection."

Coatney et al. define attacks occurring within the first 60 days after infective exposure as early, and those occurring six months or more after infective exposure as late.

"Primary attack (in part) of parasitological terminology; initial fever of Korteweg"
or on every third day (*quartan periodicity*), or of paroxysms—due in man to interpolated generations—occurring daily (*quotidian periodicity*). Paroxysms may occur on two successive days with one day interval (*double quartan periodicity*).

Associated with infection may be effects due to localization of the parasites (of falciparum) causing blocking of the capillaries of different organs, *pernicious manifestations*, the clinical characters of which are distinct from those of the normal malarial attack. Such manifestations are variously named according to the organ affected or the symptomatology.

Following upon infection may be various *sequelae*, such as anaemia, psychoses, etc. The term *malaria cachexia* has been much used to indicate a condition where the patient exhibits intense anaemia and other consequences of prolonged infection. Much of the malaria cachexia of older writers, especially in India, was, however, due to hookworm disease or kala-azar, and the term is less commonly used than formerly. Various *minor manifestations* in malarial subjects, assumed to be the result of latent malarial infection, were sometimes described—particularly when they exhibited periodicity or were modified by quinine administration—as latent or *larval malaria*, a term now little used. Haemoglobinuria occurring as a result of malarial infection, whether following quinine administration or not, constitutes the condition usually referred to in English writings as *blackwater fever* (*haemoglobinuric fever of authors*).

*Chronic malaria* is a term which has been applied by various writers to any and every manifestation of malaria occurring subsequent to a primary attack, whether due to a new infection or not. Its use is not recommended.

Parasitologically, *infection* is characterized by a period of invasion during which clinical symptoms are lacking and parasites are not demonstrable in the blood. The period without clinical symptoms is called *incubation period*, while the expression *prepatent period* refers to the time during which parasites cannot be demonstrated. These stages are followed by more or less marked parasitic and clinical manifestations (*primary attack*). This sequence is usually succeeded (except when parasites have been eradicated by a sterilizing treatment) by a more or less prolonged period in which the evidences of infection depend upon the interacting processes of multiplication of the parasites and immunity reactions of the host (see *infection immunity* or *premunition*). Infection may in this state at different times be unassociated with parasitological or clinical manifestations (*latent*), or displayed by either or both these conditions (*active*). Each such

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* Infection is used both in the sense of introduction of infective material—i.e., inoculation (by natural or artificial means)—and as indicating the resulting condition. The two usages are, however, rarely confusing.
active period, other than the primary attack, constitutes a relapse. In this connexion, a distinction may have to be made between a relapse indicated by clinical symptoms, usually associated with parasites in the blood (clinical relapse), and one indicated only by the reappearance or increase in the number of parasites as shown by microscopic examination (parasitic relapse).

In certain cases, an immediate primary attack may not occur, or may have been so mild as to have escaped attention. It frequently happens in such a case that the first attack occurs only after a long period (about nine months with certain strains of *P. vivax*)—i.e., it resembles a long-term relapse.

Certain terms are used in connexion with the study of infection and immunity. Those forms of parasite which are capable of distinction on morphological characters constitute species or varieties. Parasites of the same species or variety may, however, show differences in immunological and other characters. Where parasites giving rise to infection have been derived from some single source and have been maintained without intermixture with parasites from other sources through a number of generations, they constitute strains (of a species). The word strain is also used in a slightly different sense as implying the occurrence of forms of the parasite which behave immunologically as though distinct from other forms of the same species—i.e., the several species include an unknown number of strains which are immunologically distinct.

When parasites have established themselves in a host, the host is said to be infected. When the parasites have been eliminated through natural process of recovery or through sterilizing treatment and the host is later infected again, he is said to have been reinfected (reinfection). A super-added infection brought about in the host while the original infection is still present constitutes a superinfection. So long, however, as the original infection is present, inoculation of a host with the same strain usually leads only to a very slight and transient increase in the number of parasites, or to no observable increase. Strains of parasites which behave in a similar manner immunologically are said to be homologous. Strains which behave in a dissimilar manner immunologically are said to be heterologous. In the case of a superinfection, there may be a primary attack caused by a heterologous strain (i.e., a new infection) in an already infected host.

Where microscopic examination fails to detect infection, the blood of an infected animal inoculated into another susceptible animal may make manifest such infection; the refractoriness of the original host to superinfection may also indicate existing infection. Latent infection may sometimes be made manifest by removal of the spleen.

Malarial immunity in the vertebrate host consists of those processes which prevent infection, reinfection, or superinfection, or which assist in
destroying the plasmodia or in limiting their multiplication, or which modify the physical effects of their invasion or aid specifically in the repair of tissue. In the present state of our knowledge, all processes involved in malarial immunity appear to be related to the activity and quantum of the erythrocytic, but not the exoerythrocytic, stages of the plasmodia.

Natural malarial immunity is an innate, racial, or species immunity independent of infection. For example, man has natural immunity to avian plasmodia. Acquired malarial immunity develops as a result of antigenic stimulation by the parasite or its products. Such acquired protection may be passive malarial immunity or active malarial immunity. The former is conferred on the host by maternal transfer or by injection of specific protective antibodies. There is some evidence of maternal transfer in the first months of life in malarious areas but the second form of passive protection has not been clearly demonstrated in human malaria. Active malarial immunity is acquired naturally, consequent upon infection. Theoretically, an active immunity might also be acquired consequent upon the inoculation of killed or attenuated plasmodia or of their products.

Several aspects of active malarial immunity have been given special names which through varying usage tend to become somewhat confusing. There are, for example:

Residual malarial immunity—an active immunity consequent upon infection but persisting in the absence of plasmodia.

Premunition or concomitant malarial immunity—an active immunity consequent upon infection but also contingent on the concomitant presence of plasmodia.

Tolerance—a concomitant and perhaps persisting immunity, the primary action of which is to lessen the effect on the host of a given quantum of infection. There may be tolerance before simple or concomitant immunity has developed to the point where an increasing quantum of infection can be prevented. Tolerance and immunity are thus not synonymous terms. Tolerance may be partly compounded with a degree of racial immunity, but appears to be chiefly an active acquired immunity found most highly developed in holoendemic areas.

A person infected with a species or strain of parasite may also be infective, but in nature this is so only when the blood contains gametocytes capable of undergoing further development in the vector and when all the conditions necessary for transmission are present. The blood of an infected person is, however, infective to a susceptible host if introduced parenterally by reason of the asexual stages of malaria parasites contained in it.

A number of terms have recently been introduced to describe the use and action of antimalarial drugs. Such drugs have been commonly classified under two main headings according to their use (1) for the treatment
of the overt malarial attack (therapeutic use) or (2) for the prevention of symptoms (protective use). The second group has been further subdivided into (a) drugs which act on the erythrocytic stages of the parasite (suppressive or schizonticidal drugs) and (b) drugs which act on the sporozoites or on any succeeding pre-erythrocytic stage of the parasite. The latter were termed by James true causal or causative prophylactics.

Now that exoerythrocytic parasites have been demonstrated in mammalian malaria, the use of the words schizonticide and schizonticidal without qualification is likely to cause confusion. The following terms are suggested:

(1) blood schizonticide: a drug which acts on asexual parasites in the blood;

(2) tissue schizonticide: a drug which acts on asexual parasites in the tissues; (a) primary tissue schizonticide: a drug acting on pre-erythrocytic (primary exoerythrocytic) forms; (b) secondary tissue schizonticide: a drug acting on secondary exoerythrocytic forms.

Suppression implies the prevention of clinical symptoms by action on asexual parasites in the blood. It may be temporary, that is operative only while the drug is being taken, or permanent, denoting that no attack will supervene even after the drug has been discontinued.

A number of other expressions have been used in connexion with the chemotherapy of malaria:

Clinical cure indicates that the immediate symptoms of an attack have been relieved and that the patient has apparently recovered.

Radical cure implies elimination of the parasite from the body whether by natural recovery or as the result of treatment.

Suppressive cure implies radical cure brought about while the patient is receiving suppressive medication.

Spontaneous recovery is a term applied to clinical or radical cure brought about by nature, in the absence of specific medication.

Treatment designed specifically to prevent the occurrence of relapses is sometimes called antirelapse therapy, and treatment designed to destroy gametocytes or render them non-infective to mosquitoes, gametocyte or antigametocyte therapy. Drugs acting on the sexual forms of the parasite may be referred to as gametocidal or more properly as gametocytocidal.

The word prophylaxis is commonly used for any method of protection from disease and therefore, when applied to chemotherapy, it should properly be designated drug prophylaxis. When applied to a community, the term collective drug prophylaxis or mass drug prophylaxis is used; when to an individual, the term individual drug prophylaxis. Clinical drug prophylaxis is a term sometimes applied when the object is merely to prevent
the occurrence of overt attacks during such time as the drug is administered. Action on the asexual erythrocytic forms is, however, already covered by the word suppression, and it is suggested that the word prophylaxis when applied to chemotherapy should be restricted to action on sporozoites or other pre-erythrocytic forms (equivalent to the true causal or causative prophylaxis of James).
CHAPTER 2

MALARIA IN THE HUMAN COMMUNITY

Terms Applied to Types of Prevalence and Intensity of Malaria in the Human Community

Certain terms are used to describe various kinds of manifestations of malaria. Malaria is autochthonous when contracted locally, and imported when infection takes place outside the specified area. Autochthonous malaria natural to an area or country may be termed indigenous, and autochthonous malaria contracted from imported cases (as in post-war malaria in areas from which the disease had normally disappeared) introduced malaria. Malaria resulting from infection artificially produced in malaria therapy is known as induced malaria. When malaria is the direct outcome of human operations, especially those giving rise to increase in breeding-places—e.g., borrow-pits on railways, etc.—it is often referred to as man-made malaria.

Malaria may be described as sporadic when autochthonous cases are too few and scattered to cause any appreciable effect on the community. It is described as endemic when there is a measurable incidence both of cases and of natural transmission over a succession of years. Various degrees of endemcity have been described.\footnote{For example, the following classification, which is a slightly modified form of that proposed by the Malaria Conference in Equatorial Africa: \footnotemark[11]}

\begin{itemize}
  \item \textbf{Epidemic} malaria is a term, somewhat loosely used, to indicate a periodic or occasional sharp increase in the morbidity or mortality due to malaria. Applied in this way it comprises a number of more or less different conditions:
  \begin{itemize}
    \item \textbf{(a)} an epidemic \textit{outbreak} of malaria among a population to which malaria was previously unknown;
    \item \textbf{(b)} an occasional \textit{epidemic exacerbation} of malaria in an area of usually low endemcity;
  \end{itemize}
\end{itemize}

\footnotetext[11]{Hypoendemic: spleen-rate in children of 2-9 years, 0-10%  
Mesoendemic: spleen-rate in children of 2-9 years, 11-50%  
Hyperendemic: spleen-rate in children of 2-9 years, constantly over 50%; adult spleen-rate also high  
Holoendemic: spleen-rate in children of 2-9 years, constantly over 75%; adult spleen-rate low; adult tolerance high.}
(c) seasonal rises of malaria incidence in an area in which, between
the seasonal waves, malaria is constantly present but of low incidence
(seasonal epidemics). These waves are low or of moderate height (some-
times called minor seasonal epidemics), but they reach unusual heights at
intervals of three, five, or more years (sometimes called major seasonal
epidemics). The latter are identical with the epidemic exacerbations de-
scribed under (b);

(d) seasonal rises of malaria incidence in areas of high endemcity.

Epidemics mentioned under (a) and (b) are characterized by their
affecting all age-groups to almost the same extent. Spleen-rate, parasite-
rate, and parasite-count are high in children and adults alike; the older
adults are the only ones who may show somewhat lower rates—at least in
conditions mentioned under (b). The minor seasonal epidemics mentioned
under (c) show the same conditions, but on a moderate scale, and with
a more or less marked tendency to spare the adults. The seasonal rises
mentioned under (d) affect only the lowest age-groups, leaving the higher
ones unaffected, or almost so, at any rate in areas of the highest endemcity
(holoendemic regions).

The drafting committee believes that the use of the term epidemic
should be restricted to conditions mentioned under (a) and (b); those
mentioned under (c) and (d) should be termed seasonal rises of malaria
incidence. With this restriction there is no objection to retaining the terms
epidemic outbreak for small communities, regional epidemic for large areas,
and malaria epidemic of (tropical) aggregation of labour for conditions
arising from importation of non-immune labour into malarious areas, for
the sake of satisfying the needs of large-scale engineering or planting
activities.

Terms commonly used to designate the amount or degree of malaria
are incidence, prevalence, and intensity. Incidence is commonly employed
in statistical, epidemiological, or medical usage as referring to the number
of cases, or to the percentage of infected persons, in an area. Prevalence
is a loosely applied term indicating the frequency of, or liability to, infe-
tion from malaria in an area, or the degree of splenomegaly, or the per-
centage of persons with parasites in the blood, etc. Intensity may be used
in the sense of severity of infections—i.e., parasite density—or of likeli-
hood of an individual in the area to contract the disease. All these terms
are preferably replaced by more precise conceptions indicating the par-
ticular manifestation of infection that is referred to.

The word endemcity is useful as giving a general measure of the endemic
prevalence of malaria. Methods which aim at recording and measuring
the endemic and epidemic prevalence of malaria in communities in a numeri-
cal fashion form the subject of malariometry.
Measurement of Malaria: General

A good deal of uncertainty exists as to the use of rate and index in certain terms connected with the measurement of malaria. Thus some writers have replaced the old-established spleen-rate by spleen index on the assumption that this usage is more nearly correct.

The word rate which usually carries the idea of some simple form of proportion, is that mostly used in medical statistics—e.g., death-rate, birth-rate, stillbirth-rate, etc. The word index is mostly used where the proportion in question is not the direct measurement required but only indicates this; for example, the refractive index is the size of an angle, but it indicates measurement of a property, i.e., refractivity. Rate implies a simple and direct observed proportion, index a measurement of one type of value used to indicate measurement of another. Thus the percentage of palpably enlarged spleens in a group would be the spleen-rate of the group, but is an index of the endemicity of malaria in the population. The drafting committee believes that, on the whole, rate is here most suitable, especially as it has the claim of long usage and custom. Where necessary, index may be used—e.g., splenometric index, which is not a rate. Ratio may be used where the proportion of one measured specified value to another is expressed as a figure, relating to unity, and not as a percentage.

The morbidity-rate (or morbidity) from malaria would be (theoretically) the proportion of persons sick from malaria in a given unit of time. Such a rate is rarely measurable, and morbidity-rates as actually employed are usually based on admissions to, or attendances at, hospitals or dispensaries. These are very dependent on the circumstances controlling admission or attendance. Frequently, also, the size of the actual population to which such figures relate is unknown.

The true mortality-rate (or death-rate) from malaria is in practice as unascertainable as the true morbidity-rate, but for different reasons. In this case, the recording agency may be effective as regards the record of deaths, but may often give little information of real value because so many of the deaths recorded as due to malaria are in reality due to other conditions and, on the contrary, deaths directly or indirectly due to malaria are often not recorded as such. This is especially likely to happen since mortality from malaria in a general community is preponderantly infantile, and even with medical supervision diagnosis in such cases is difficult. Data of this type may, however, be of use in indicating seasonal and other variations in malaria even though, as absolute values, they are unreliable.
For the above reasons, the *total deaths* (i.e., deaths from all causes) in an area may, in some circumstances, be even more valuable as material for statistical study than the returns of malaria mortality. This applies particularly to conditions where malaria occurs in epidemic form and there is good general registration of deaths, independently of any question of correct diagnosis of the cause of death. This is because the temporary effects of the disease here cause considerable or even enormous variation in the record of total deaths, such effects being evidenced by characteristic peaks in the graph of total (weekly) deaths, the *epidemic rises* of Indian observers. The measure of an epidemic rise is the *epidemic figure*, or number of deaths in a selected epidemic month divided by the normal monthly deaths for the area. By plotting such epidemic figures for numerous small registration circles, the intensity and distribution of regional epidemics can be mapped (for description of the method, see Christophers, Sinton & Covell).

It is often required to use data, not for the whole community, but for a particular age-group or -groups. In specifying such age-groups there is some difficulty in avoiding ambiguity as to the exact age-group referred to, especially in the endeavour to do so briefly, as in compiling tables. Age is most commonly taken as that on the last birthday (method A). In this method of stating age, a two-year-old child may be of any age from two to just short of three years. In malaria field-work, especially in the tropics, where the age of children has to be guessed or given approximately, the age-figure is more nearly that of the nearest birthday—i.e., a two-year-old child may be of any age from one and a half to two and a half years (method B). To describe a child as two years and over but under three years (as in method A) and, especially when defining age-groups, to avoid ambiguity in such a fashion, is both troublesome and clumsy, and the best way to obviate such redundancy while retaining accuracy would appear to be to adopt a convention by which it is understood that any given age-figure includes children from that age to just under the next year of age.

The following age-grouping is recommended:

<table>
<thead>
<tr>
<th>Group</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-11 months</td>
<td>Infants, babies</td>
</tr>
<tr>
<td>12-23 months</td>
<td>Children under two years of age</td>
</tr>
<tr>
<td>2-4 years</td>
<td>“Toddlers”, pre-school children</td>
</tr>
<tr>
<td>5-9 years</td>
<td>Juveniles</td>
</tr>
<tr>
<td>10-14 years</td>
<td>Adolescents</td>
</tr>
<tr>
<td>15-19 years</td>
<td>Young adults</td>
</tr>
<tr>
<td>20 years and over</td>
<td>Adults</td>
</tr>
</tbody>
</table>

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7 Thus the age-group 0-2 of some authors is identical with the age-group 0-1 of others employing a different method of statement.

* The strictly accurate method would be to record ages in years with the necessary fractions (method C), but this in practice, unless very small groups are used, would come down to one of the above methods.
Where ages are recorded by method B, these groups would not be
strictly accurate, but, as method B is admittedly used in circumstances
where the age given is approximate, such inaccuracy as is involved would
usually not be important and the age-groups given would indicate suffi-
ciently well what is intended. In all cases it is desirable that a clear state-
ment should be given as to any convention used, and the method of deter-
mining age stated.

Terms Used in Measurement of Malaria by Examination of the Blood

(a) General considerations

A measure of the incidence or frequency of malaria would be the per-
centage of persons in a given community who have the parasites of malaria
in their blood. The difficulty in regard to such a value is that not all the
infected persons in the community are detected by a blood examination.
Hence the number found positive is not exactly equal to, and may be widely
different from, the true infection-rate. Before discussing the terminology
and the definition of such terms as parasite-rate, parasite density, infection-
rate, etc., it is therefore desirable to refer briefly to the question of the
relation between results obtained by examination of the blood and the
actual blood condition present. This will be most readily done by con-
sidering the results obtained from a more and more prolonged examina-
tion given to a series of blood-films from an infected community, pre-
ferably a child community in which malaria is more or less static (see
page 40, footnote v).

In any such community, many of the infections are likely to be of a
relatively high order, say 1,000 parasites per mm$^3$ or over. All such infec-
tions will be detected by a minimal examination, say one or two fields of
a thick film. However, a number of infections of a smaller order, say
100 parasites or less per mm$^3$, would remain undetected. Further, more
and more such infections would be brought to light as more and more
time were given to the examination—i.e., as more and more blood were
examined. On the average, it is clear that, to find one parasite when these
number 1,000 per mm$^3$, one-thousandth of a mm$^3$ of blood must be
examined—i.e., approximately 5,000 red blood corpuscles (r.b.c.). To
detect an infection of 100 parasites per mm$^3$ on the average, it would,
however, be necessary to examine 50,000 r.b.c., or about 0.01 mm$^3$ of
blood—i.e., about 100 microscopic fields, each containing 500 r.b.c. in a
thin film, or an equivalent number of fields in a thick film.

Two important points here arise: (1) that without some indication of
the infection intensity (that is, the value of the infections which different
positive results represent), a very imperfect idea of the real degree of parasitism is given by the parasite-rate (e.g., this may be made up entirely or mainly of very small infections, or of quite large infections, obviously indicating a different state of affairs in the two cases); (2) that the rate itself is actually largely dependent on the number of light or heavy infections present, since the larger the infection the greater the likelihood that it will be detected in any given degree of examination.

It will be clear, therefore, that it is desirable when specifying infection in a community to give not only the parasite-rate, but also an indication of the parasite density, both of which should be included in a parasite survey. These two values are required to cover the two separate conceptions of the frequency or incidence of infections and the intensity or number of parasites which these infections represent. An even more complete specification of the characters of infection in a community is to be obtained from a study of the frequency distribution of the values of infections. The fact that infections may arise from different species of parasite has also to be considered.

(b) Parasite-rate

The parasite-rate should always be defined in terms of the group examined. Thus, the percentage of adults showing parasites is the adult parasite-rate, and that of children aged 0-11 months, the infant parasite-rate. Similarly, the parasite-rate at any age should be specified as the parasite-rate of that age-group.

The value ascertained is to some extent dependent on the time devoted to the examination of each slide. With very little increase of labour, however, both the parasite-rate and the parasite density can be simultaneously obtained by using one of the simple routine counting-methods of examining slides described in the section on parasite density (see page 33). The parasite-rate can then be given as relating to a definite minimum infection limit, as there explained.

The age-group 2-9 has often been used for measurement of the degree of premunition in the community. The same age-group is also used for the spleen-rate, which remains very constant within these age limits. This group, however, includes two classes—“toddlers”, and juveniles, who often show great diversity as regards parasite-rate and parasite density. It would, therefore, seem preferable to treat these two classes separately. The group of 0-11 months has an importance of its own (see infant parasite-rate, page 41). The adult parasite-rate is also important.

The same considerations hold good for the parasite-rate as are given under the spleen-rate (see page 37) in regard to the source of the children examined, and if schoolchildren are utilized, this should always be stated.
Any possibility that the children have been subject to antimalaria medication should be noted.

(c) Parasite density

In computing the parasite-rate, no account is taken of the fact that the infections encountered may vary greatly in intensity—i.e., in the number of parasites characterizing them. The number of parasites per mm$^3$ in any given individual is the parasite-count. The mean or average parasite-count for a community or age-group constitutes the parasite density, which is thus a measure of intensity of infection in a community as judged by the numerical value of infections. The parasite density can be expressed either as the mean parasite-count (mean number of parasites per mm$^3$ taking negative observations into account in arriving at the mean), or as the mean positive parasite-count (where negative observations are excluded and only the value of actual infections is taken).

Unfortunately, the enormous variation in the numerical value of the infections usually encountered makes these means less satisfactory data than they might otherwise be. Thus, if one infection is of very great magnitude, it may grossly swamp the effect of a majority of much smaller counts. Nevertheless, when infections are reasonably graded and where a sufficient number of children is utilized, the mean positive parasite-count may be a very valuable figure. In practice, it may be desirable to omit from the mean any grossly outlying values, or better, some other measure than the mean may be used—e.g. the mode or the quartiles obtained from an array (see parasite frequency distribution, page 34). The use of the geometric mean—i.e., the square root of the product of the values—is another method of minimizing extreme deviations in the upper range.

For accurate enumeration of parasites, a suitable technique must be used, for example, small measured quantities of blood spread over a known area, or Sinton's $^{28}$ fowl-corpuscle method. The following, however, are methods in use to obtain approximate results:

1. counting the parasites seen in a thick or thin film respectively in a given time of examination;

2. counting the parasites in a given number of microscopic fields in a thin film or an equivalent number in a thick film, using, if possible, a square ocular aperture of known area-relationship to the whole field;

3. counting the parasites in relation to the number of red cells or leucocytes simultaneously encountered, using a square ocular aperture of suitable area. The former method is applicable only to thin films where alone the red cells are left intact, and the latter to thick films where alone the leucocytes are sufficiently uniformly distributed for such a method to be used.
Use of a direct time-limit is generally agreed to be unsatisfactory. Perhaps the method of counting the parasites in 100 fields of a thin film is the simplest routine method, the same objective and eyepiece being employed, or any necessary adjustment in this respect made. Since the rough average number of red cells in the field for a given objective and eyepiece can be ascertained, results may be expressed as parasites per mm$^3$. If thick films be made of a roughly standardized thickness, counts obtained by examining so many fields may also be roughly expressed in parasites per mm$^3$. Counting the leucocytes similarly enables a rough quantitative result to be given.

The question arises as to the value of such very approximate determinations. The natural reaction is to dismiss such methods as too unreliable to serve any useful purpose. Further consideration will show, however, that the enormous range in the value of the infections (lying between 100 or less, and 100,000 or more, parasites per mm$^3$) is an asset, since the order of infections becomes of greater significance than the exact accuracy of the results. The value of such rough methods is also evidenced by their obvious utility in practice. Thus a record of + or — gives no indication whatever of the numerical value of a result, nor is it found by experience that such entries as scanty, numerous, etc., give much more. On the other hand a recorded count, however simple, may be a useful indication, sufficient for many purposes.

(d) Parasite frequency distribution

From the data giving the numerical value of infections in a community, it may be useful to study the parasite frequency distribution. The usual method of setting out the frequency distribution (i.e., the numbers in any given class as ordinates and the measurement specifying the classes as abscissae) is often less useful in this case than an array (infections arranged in order of magnitude spaced at regular intervals along the base line).

An informative study of infection values can also be made by plotting the infections detected at successive numbers of fields examined. This can be done by noting in the case of each slide the number of fields before a parasite is first encountered, and plotting a curve on the basis of the results obtained. The level at which such a curve becomes horizontal is termed the parasite asymptote as a form of expression of the true infection-rate (absolute parasite-rate). Its determination has the effect of bringing intensive examination to bear on the negative films and thus exploring the frequency of the lower-grade infections.

(e) Species prevalence

So far, infections have been considered without reference to the fact that they sometimes arise from one species of parasite and sometimes from
another or, as often happens, from two or more species, so that the number of infected persons is not the same as the number of infections, when considering each species separately. Commonly, infections of one species are predominant in certain areas, so that in general the parasite-rate and parasite density refer in practice more or less satisfactorily to such species. The question of a plurality of infections has, however, to be given consideration in relation to terms employed. Such terms are rather apt to be ambiguous and the following is perhaps the usage to be recommended where it is necessary to employ them.

The percentage of individuals found infected with any given species is the species infection-rate for that species—e.g., the falciparum infection-rate. The percentage of infections from any given species in the total infections found is the relative prevalence of that species. A statement giving in some recognized order the relative prevalences of the species found is the parasite formula (the figures given totalling 100).

**Terms Used in Measurement of Malaria According to Enlargement of the Spleen**

(a) **General considerations**

The object of splenic examination is to determine: (a) the proportion of individuals with demonstrable enlargement of the organ, and (b) the degree of enlargement.

The first to measure malaria by determining the proportion of persons in a community showing splenomegaly—i.e., by the spleen-rate—was Dempster in India, 1848. Ross (in his report on Mauritius, 1908) was the first to make systematic use of the size of the enlarged spleen in a malarious community to measure malaria. Numerous observers have subsequently utilized these methods in studying malaria prevalence and in mapping malaria, and the subject has become somewhat complex, largely owing to the different ways of obtaining and studying the data. It is desirable as far as possible to bring these varying methods and usages under a common terminology and to simplify the issues by a clear statement of underlying principles.

While the spleen-rate would most simply be regarded as the percentage of persons in any community showing splenomegaly, it has been found that the rate in children often differs greatly from that in adults and, for various reasons, is the more representative as a measure of malaria. The spleen-rate as ordinarily understood and used by malarialogists has therefore come to be the spleen-rate in the children of a community, while the spleen-rate in adults is separately distinguished as the adult spleen-rate.
The age-group usually selected is that which includes children in their third to tenth year of life—i.e., age-group 2-9 years. Roughly, this includes children from the time they have begun to run about "toddlers" until just before they become adolescents. Young babies (age-group 0-1 year) are commonly carried in their mother's arms and cannot be examined under the same conditions as children who have begun to run about. Also many babies, especially those who have not passed through a fever season, may not yet have had time to develop splenomegaly. In the age-group 10-14 years, the spleen-rate has often become considerably reduced and, without knowledge on this point, cannot be assumed to be the same as in age-group 2-9, during which period it is generally very constant. In adults, the spleen-rate may even be in reverse relation to that in children—i.e., a very intense malarial infection with a high spleen-rate in children may be associated with a greatly lowered adult spleen-rate. In other circumstances, both the child spleen-rate and the adult spleen-rate may be high.

In relation to both parasite determinations and observations on splenomegaly, the question of the source of the children examined is important. The parasite-rate and also the incidence of splenomegaly is liable to be greater the lower the social status of the children. For this and other reasons, schoolchildren are apt to show lower rates than children collected in villages or in the streets of a town.

In general, as described later (see page 38), there are among malariologists two main methods of procedure for palpation of the spleen when determining the spleen-rate: that in which the subject is examined standing, and that in which the subject is examined lying down. Comparison of spleen-rates as taken in different countries by different observers is greatly facilitated by a record of the size of the spleen (see pages 38, 39), this

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8 Because of this constancy, there is not the same desirability of splitting up this age-group into ages 2-4 and 5-9 as there is when dealing with parasite density. The indices relating to spleen size are also not apt to change during the age-period in question.

The following are reasons which may lead to a reduced rate in schoolchildren:

1. Social status is often relatively high;
2. Children below the age of 5 are but little represented;
3. Sick children are likely to be absent;
4. School medication may influence results and the taking of antimalarial drugs may be more frequent owing to education and higher social status.
5. The children are often drawn from a wider area—e.g., from villages to a school in town—and may not reflect the actual local conditions so well. (See Christophers, Sinton & Covell.)

On the other hand, the much larger samples obtainable in schools, the possibility of examining the same group at different times, and the greater information available about the child are distinct advantages. Much depends upon the circumstances in different countries, areas, etc., so that it is impossible to lay down a strict rule, but on the whole some allowance must be made for a lower rate in schoolchildren where comparison is being made with rates obtained on village or street children, and it is therefore desirable that it should be so stated when schoolchildren are being utilized in determining rates.

u Another method, as employed by Schüffner, consists in examination of the subject sitting.
being one of the reasons why it is important to indicate the proportion of different-sized spleens as well as merely to determine the spleen-rate.

The methods employed by different malariologists in measuring and recording the size of the spleen are dealt with on pages 38, 39. In general, it may be said that measurement of the size of the enlarged spleen in a community involves the recognition of certain definable classes of size, the numerical prevalence of which in a given community can be ascertained and recorded. From such records, certain average values—e.g., average spleen, average enlarged spleen, etc.—may be arrived at which are intended to serve as an indication of the degree of splenomegaly present. Since such information may be useful, not only as a matter of theoretical interest, but also as a means of comparing the results of different observers, it is greatly to be recommended that data obtained regarding splenomegaly be recorded in some such form as is given in fig. 8. By noting the data in this way, both the spleen-rate and any other index desired can be readily calculated at any time.

FIG. 8. SCHEMA FOR RECORDING SPLENOMEGALY DATA

<table>
<thead>
<tr>
<th>Class of spleen *</th>
<th>Age-group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-1 year</td>
</tr>
<tr>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

* See classification on page 38.

(b) Spleen-rate

As noted earlier, the spleen-rate has usually been defined as the percentage of children aged 2-9 years showing palpable enlargement of the spleen. A similar proportion in adults is the adult spleen-rate, and the rate may also be determined for any desired age-group. The spleen-rate is an extremely valuable measure of endemic malaria, since it is not so liable as the parasite-rate to rapid seasonal changes. A further advantage is that it involves so little expenditure of labour.

The need for certain conventions in taking the spleen-rate, to give as much uniformity as possible in the results, has been generally recognized.
(c) **Measurement of spleen**

Many ways of classifying splenic enlargement have been proposed, but the following method is becoming a generally accepted standard where actual centimetre measurements are not used:

<table>
<thead>
<tr>
<th>Class of spleen</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>A normal spleen, not palpable even on deep inspiration</td>
</tr>
<tr>
<td>1</td>
<td>Spleen palpable only on deep or at least more than normal inspiration</td>
</tr>
<tr>
<td>2</td>
<td>Spleen palpable on normal breathing but not projected below a horizontal line half-way between the costal margin and the umbilicus, measured along a line dropped vertically from the left nipple</td>
</tr>
<tr>
<td>3</td>
<td>Spleen with lowest palpable point projected more than half-way to the umbilicus but not below a line drawn horizontally through it</td>
</tr>
<tr>
<td>4</td>
<td>Spleen with lowest palpable point below the umbilical level but not projected more than half-way towards a horizontal line through the symphysis pubis</td>
</tr>
<tr>
<td>5</td>
<td>Spleen with lowest palpable point below the lower limit of group 4</td>
</tr>
</tbody>
</table>

The *average enlarged spleen* or AES is represented by a number arbitrarily determined by multiplying the number of individuals in each spleen-class, except class 0, by the spleen-class number, adding these products, and dividing the total by the number of those whose spleens are palpable. Since the average enlarged spleen is arbitrarily determined, it is essential for comparison that the above classification of splenic enlargement and no other be followed exactly.

Subjects may be examined, as previously noted, in a standing, sitting, or recumbent position, preferably the last-named. Every effort is made to secure relaxation of the abdominal wall and to avoid having the palpating hand separated from the abdominal skin by intervening clothing. It is emphasized that spleen palpation requires special training because it is easy to mistake something else for an enlarged spleen, especially a class 1 spleen. The drafting committee regards with great scepticism all spleen-rates of over 10% obtained in non-malarious communities, except in the recorded presence of kala-azar or acute exanthematous diseases, or in a group very recently vaccinated against smallpox.

Where greater accuracy of measurement is required the following procedure is recommended: The apex (i.e., the point of furthest projection) of the spleen is located by a touch of the finger and marked with a spot from a grease pencil. The distance of this spot from (a) the umbilicus (A-U) and (b) the middle line of the body (A-M) is then measured to the nearest centimetre with a tape-measure. The position of the apex is thus determined by triangulation. The distance from the nipple to the umbilicus (N-U) is also recorded. The N-U measurement is for use as an indicator
with a table by which the A-U and A-M measurements may be corrected for comparison with a "standard" child of average age 6.4 years, sitting height 60 cm, and N-U measurement 21 cm. The position of the apex of the average enlarged spleen is calculated by adding together the corrected A-U and A-M measurements in separate columns and dividing each total by the number of enlarged spleens recorded.

The reason for using the umbilicus rather than the costal margin for measurement of the enlarged spleen is that it is a point and not a line, and is subject to less variation than any other point of reference except the nipple. Moreover, since the A-U line runs more or less transversely across the abdomen, vertical variations in the position of the umbilicus are not reflected to an equal extent in this measurement.

A modification of this method, using the N-U and A-U measurements only and omitting the A-M, has been used by the staff of the Malaria Institute of India in their routine surveys for 25 years, during which many thousands of spleen measurements have been recorded. It has been found perfectly practicable for general field work, and occupies very little more time than any of the other systems advocated. A written description is apt to create an impression that the method is much more complex than is actually the case, and this has no doubt militated against its more general adoption in other countries.

\[ (d) \] Frequency distribution of classes of enlarged spleen

Data giving the number of enlarged spleens of different measurements can be studied from the point of view of frequency distribution of the classes. Such frequency distribution, unlike the parasite infection frequency, is well displayed in frequency curves of the usual type. The curve given is a valuable aid to the study of splenomegaly in malaria, since the frequency distribution of different classes of spleen is the fundamental phenomenon on which such values as the average enlarged spleen are dependent.

Indices of Endemicity

\[ (a) \] Endemic index of Stephens & Christophers

Under this term endemic index, the parasite-rate for children aged 2-10 years was used by Stephens & Christophers, for purposes of comparing and mapping endemic malaria. Although this rate has been extensively employed, it has been found more convenient in practice to use the spleen-rate for this purpose. It is undesirable, therefore, to have a term endemic index which is distinct from the criterion most usually adopted in measuring endemicity—the spleen-rate. It is also liable to be confused
with the *endemic index of Ross*,\(^2\) which is of a different nature (see page 41). For these reasons, the use of the term endemic index is best discontinued.

(b) Spleen-rate as index of endemicity

In practice, the spleen-rate has been more widely used in measuring and mapping malaria than any other method. Where malaria is static \(\textsuperscript{v}\)—the most usual condition in tropical communities—the spleen-rate obviously gives a remarkably good measure of the endemicity of malaria. Even in epidemic conditions, it affords an immediate indication of the prevalence of infection. While no single figure can be expected to express all the detailed phenomena of malaria prevalence and intensity, the spleen-rate appears to give, in a broad and general sense, the best measure of the *malariousness* of a place or community. The spleen-rate might well have been used as an agreed index of endemicity, and named the endemic index. This, however, would now cause confusion and it is on this account undesirable to give it this name, though in actual practice it is the usual datum line to which malaria phenomena in communities are referred.

(c) Splenometric index

The *splenometric index* is a single-figure index (spleen-rate \(\times\) average enlarged spleen) designed to include degree of splenomegaly as well as the spleen-rate (Parrot & Cataneli \(^2\)). This index has the advantages and disadvantages of any composite index, and therefore it is desirable always to give the spleen-rate to which it relates.

(d) Average enlarged spleen

Where malaria is static it appears, on the average, to produce in those infected a certain relatively fixed degree of splenomegaly. This mean splenomegaly in children aged 2-9 years, *average enlarged spleen* (*AES*), has been found by careful researches in India to be usually much the same where the malaria incidence is low—i.e., where splenomegalic individuals form a small proportion only of a non-infected community—as it is in conditions where the whole community is heavily infected. This same mean splenomegaly in children is characteristic also of single infected families (small malarial foci) among a surrounding non-infected community. A moderate increase, however, occurs when the spleen-rate of the community exceeds about 80\%. Reduction below this more or less fixed value can, however, occur, for

\(^{v}\) By static malaria it is not meant that there is no variation at all in the spleen-rate, which commonly does vary to some degree even in the most intensely infected villages, but that a more or less constant endemicity is present, as against conditions where malaria is freshly introduced, or is dying out as the result of mass treatment or of a long period without new infections.
example, in Europe or elsewhere when different recovery conditions in the host, shortness of the malaria season, mass treatment, or other factors bring about such a result. A reduction in the average enlarged spleen is therefore a significant fact, over and above the fact of reduction in the spleen-rate, and it may have value in judging the malarial conditions relative to a community.

(e) Malaria-rate of Ross

This is the number of actually infected persons (infant, child, or adult) expressed as a percentage. It is not directly ascertainable and can only be deduced or estimated from such information as the parasite-rate and/or spleen-rate, etc. The term is undesirable since it is ambiguous and, apart from this, suggests morbidity-rate rather than the meaning actually intended.

(f) Endemic index of Ross

This was defined by Ross as the number of children aged 2-10 years showing evidence of malaria by either presence of parasites or spleen enlargement or both. While possibly giving a nearer approach to the true infection-rate, the method is dependent on the same limitations as are inherent in the parasite-rate or spleen-rate, in that it does not necessarily indicate the number accurately. Apart from other considerations, the term endemic index cannot now be used without being liable to cause confusion.

(g) Macdonald's index

Making the assumption that all children showing enlargement of the spleen are almost certainly infected, whether shown to be so by ordinary blood examination or not, Macdonald has suggested an index for estimating the true infection-rate, i.e., the proportion of children under different conditions who show parasites when enlargement of the spleen is present.

(h) Infant parasite-rate

The parasite-rate in children aged 0-11 months has been shown to have value as an index of liability to contract infection in a given locality; it was termed transmission index by Barber, Rice & Mandekos.
CHAPTER 3

TERMS APPLIED TO THE VECTOR

The Name Anopheles

Some hesitation is often felt as to whether to write Anopheles, "Anopheles", Anopheles, anopheles, or anopheline. A good working rule is to employ Anopheles only when giving a definite zoological value to the name, and to use anopheles or anopheline whenever it is merely a question of colloquial designation.

Species and Varieties of Anopheles

About 400 species of anopheles are known, forming the tribe Anopheolini, one of three tribes into which the sub-family Culicinae (or true mosquitoes) of the family Culicidae is divided. All but a very few rare forms of the tribe are, however, included in the genus Anopheles, of which several subdivisions are recognized.

It is usual, at least once in any communication, to accord to any species dealt with its full zoological name.

Named forms of subspecific rank are recognized in the case of certain species. These have the character of species but, either because they are so nearly related to the species to which they are allocated, or for certain other reasons, they are conveniently maintained as a group of subspecies rather than as so many distinct species. Such subspecific forms are accorded the rank of subspecies and in nomenclature are distinguished by a third term (trinomial name)—e.g., A. jeyporiensis jeyporiensis James, 1902, and A. jeyporiensis candidiensis Koidzumi, 1924.

The term race is often employed in genetic and other studies to indicate subspecific differentiation not amounting to an actual definable morphological distinction. It has something of the character of subspecies or variety but, whereas the essence of the latter distinction is morphological, the distinctions upon which races are based are usually genetic.

Stages of Growth and Development

(a) Metamorphosis

The stages of metamorphosis are: the egg, larva, pupa, and imago (often termed adult). The liberation of the larva from the egg is most
commonly referred to as hatchling. The casting of the successive larval skins is termed ecdysis, the first larval stage being that from hatching to the first ecdysis. It is a point of practical importance in detection of the stages that, while the body of the larva grows during the stage so that size in the same stage may be very different, the head remains unchanged and therefore offers a ready means of determining the stage. The fourth ecdysis, which determines the final or completed larval stage (fourth-stage larva), results in pupation, this being followed in due course by emergence of the imago. Deposition of eggs by the female constitutes oviposition. The site chosen for oviposition and subsequent development of the larvae in nature is the breeding-place.

Some terms used in connexion with artificial rearing require consideration. The statement that a species has been reared in captivity may mean simply that larvae or eggs have been collected and subsequent emergence of the adults obtained, or may indicate that fertilization has been brought about under experimental conditions, with subsequent development. It is desirable to make use of distinctive phraseology in the two cases and, while bred out in captivity might serve for the first case, reared in captivity might be reserved for the second. The eggs (which may be examined or subsequently bred out for examination) deposited by a female at any one oviposition are referred to as a batch.

(b) Gonotrophic cycle

Fertilization is evidenced by packing of the spermatheca with spor- matozoa, the proportion of fertilized females in nature being the fertiliza- tion-rate. A blood-meal, until it is digested, is evidenced by the presence of blood in the midgut. As the blood-meal is digested, the ovaries enlarge. A female containing blood in the gut is commonly referred to as a fed female, and one which has not fed on blood, or in which the blood has been completely digested, as an empty female. If the ovaries are perceptibly enlarged, the insect is designated a gravid female.

Development of the ovaries is indicated by various stages of the follicles, as follows:

Stage 1 — ovum without marked granules
Stage 2 — granules present and occupying up to half the follicle
Stage 3 — granules occupying over half the follicle, which, however, is not elongated
Stage 4 — follicle elongated or having shape of mature egg, but superficial structures not evident
Stage 5 — egg is fully formed and floats visible

For a detailed description of these stages, see Russell, West & Man- well.24
Females which have not previously oviposited are said to be nulliparous, but those which have previously made one or more ovipositions are multiparous. In the former, the follicle must pass through all five stages of development; in the latter, the first two stages have already been completed by the oncoming follicle before oviposition so that the time of development required, as counted from one oviposition to another, is correspondingly shortened. In the case of multiparous females, an indication that they have previously oviposited is given by enlargement of the ovarian tube and sometimes by a retained egg.

The complete cycle from time of feeding to oviposition is the gono-trophic cycle, which may extend over a period of two, three, or more days. Where the ovaries remain in an undeveloped state while the insect continues to take blood-meals, the condition is described as gonotrophic dissociation.

(c) Age

Determination of the age of females, so far as this can be ascertained, is important. Stage 1 ovaries indicate a newly emerged adult (24 hours or under). All other ovarian stages indicate only a phase of a gonotrophic cycle, and do not indicate whether this phase belongs to the first or a subsequent cycle, except as shown by the condition of the oviducts or a retained egg undischarged at the last oviposition, these being evidence that at least one cycle has been passed through.

An indication of age may also be given by the general condition of the insect or by the appearance of the wing. The following method of classification is frequently used:

Class 1 — wing markings clear and fringe complete
Class 2 — wing markings fairly clear, but fringe worn
Class 3 — wings shabby and fringe much worn
Class 4 — wings threadbare

Life History and Behaviour

(a) Breeding-places

The collections of water from which anopheles are derived are the breeding-places (in relation to any specified species). These may be temporary or permanent. Temporary breeding-places which are dry at the moment of inspection, and likely breeding-places not actually showing larvae, form potential breeding-places. The number of adults (per unit of time, etc.) deriving from breeding-places is the anopheles output.
(b) Dispersion

The spread of anopheles from their breeding-places in search of food, etc., constitutes dispersion. Distance of dispersion is the mean or maximum distance, as the case may be, to which individuals disperse from their breeding-places. The distance which may be covered under some special conditions—e.g., preceding hibernation—is long-distance dispersion. When anopheles reach their final destination by passing from house to house, or from shelter to shelter, in an unknown succession of steps, this is spoken of as infiltration (of an area). When anopheles are brought into an area by vehicles, etc., this is described as passive dispersion or transportation. When anopheles are carried long distances by wind, the phenomenon may be described as wind dispersion.

It seems desirable to distinguish between the distance a mosquito can fly at a single effort, flight range, and the total distance it may cover after many such flights, here given as distance of dispersion. The term effective flight range refers to the distance from a breeding-place that the females of a given species travel in numbers sufficient to maintain endemic malaria, or to cause an epidemic.

(c) Feeding and resting habits

The source from which an anopheles obtains its blood-meal is the host. The place where a blood-meal is obtained is the feeding-place, and the places where anopheles are found resting during the day are the day resting-places.

The blood-meal may be obtained from man or from cattle or other animals. The names anthropophilic, zoophilic, and even neutrophilic have been given to species of anopheles to indicate, respectively, a supposed preference for feeding upon man, upon cattle, or upon both indiscriminately. Such names do not well represent the facts and are liable to give rise to misconception. Actually, all anopheles usually include among possible hosts a number of animals, which may include man, the order of preference for different hosts (host preference) varying with the different species. The animal most preferred is the host of predilection.

The proportion of freshly fed anopheles giving a positive precipitin reaction for human blood is the human blood ratio for the particular conditions in which the captures have been made. Such a ratio gives some indication of the degree of host relationship to man under the particular circumstances and is closely bound up with the extent to which particular species under given conditions act as vector species. The human blood ratio has also been termed the anthropophilic index.
Where, owing to host preference such as attraction to cattle or other domestic animals, there is reduction in the number of anopheles feeding on man, this is referred to as animal deviation.

Day resting-places may be human habitations (houses), places where animals are kept (stables, as a general covering term), outlying unoccupied sheds, etc. (shelters), or undercut banks, undergrowth, caves, etc. (natural shelters).

The conditions of temperature and humidity in the immediate surrounding space in which a mosquito lives when resting or otherwise, as distinct from the temperature and humidity of the general atmosphere, constitute microclimates. Such a microclimate often differs greatly from that of the outer air or even of the room occupied.

(d) Other habits and behaviour

In the case of anopheles, as with most mosquitoes, oviposition is dependent on a blood-meal. Rarely, as in a certain species of Culex, the necessary store of nutriment for the eggs is accumulated in the larval state, oviposition occurring although no blood-meal has been taken by the imago (autogenous behaviour).

With some species, fertilization of the female takes place without difficulty under experimental conditions in a limited space, while with others mating takes place only under conditions which permit unrestricted swarming of the males. The two forms of behaviour have been termed stenogamous and eurygamous respectively.

Certain species tide over the cold season or winter (wintering) as egg, larva, or adult. In the case of the adult this wintering is termed hibernation. When the female develops fat and ceases to feed and oviposit, hibernation is said to be complete. In certain cases, the female, while ceasing to oviposit, remains more or less active and continues to take blood-meals (partial hibernation). Such a condition (gonotrophic dissociation) may occur long before the actual onset of winter conditions, and come to an end before winter is over.

When, in resistance to a dry hot season, special adaptation takes place, this is referred to as aestivation.\(^7\)

The terms tropism and taxis are applied to various reflex urges such as might cause a mosquito to be attracted or repelled, or to fly in a given direction.

\(^7\) It has not been shown that, in the case of anopheles, actual modification of the life processes takes place in hot dry conditions, though some specialization in habits may possibly occur under such conditions.
The Anopheles Community

The total number of anopheles in a village and its immediate surroundings is the *anopheles population*. The number of anopheles per person, per room, per house, per square foot of resting surface, per time-period, or per standard trap, is the *anopheles density*. The *critical density* is the density of the vector species, relative to any of the previously-mentioned standards, below which malaria tends to disappear.

Enumeration of the proportion of males and females, of nulliparous and multiparous females, of females of different classes of ovarian development, of fed and empty, or fertilized and unfertilized, females, etc., gives the *anopheles population composition*. The number of females entering the area nightly from outside is the *nightly influx*, and the number leaving for oviposition, etc., the *nightly efflux*. The number of newly hatched mosquitoes (stage 1 ovaries) entering the area is the *nightly newcomer influx*. The redistribution of the anopheles population following various movements of the individual insects at night is the *nightly turnover*.

Where different species enter habitations, etc., at different times of the night, this has been termed *crepuscular succession*.

Infection in the Anopheles Community

The percentage of female anopheles caught in nature showing sporozoites on dissection of the glands is the *sporozoite-rate*. The percentage showing oocysts on dissection of the midgut is the *oocyst-rate*. These rates should be related to some specified species. They should also be accompanied by information as to the source of capture—e.g., houses, stables. In the case of small villages, uniform admixture of anopheles may, however, usually be assumed.

The percentage of anopheles caught in nature showing either sporozoites in the glands or oocysts in the midgut has been termed *index of natural infection*. The percentage of anopheles experimentally infected, showing either sporozoites in the glands, or oocysts in the midgut, has been termed *index of experimental infection*.

The term *infective density* is applied by Davey & Gordon to the average number of female anopheles found with sporozoites in the glands per room per day. The term relates to systematic research carried out over a considerable period in which the anopheles density and infective density were

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* All terms in this section should strictly be applicable to the conditions for a particular species only, since there is no guarantee that all species present in the community are in the same biological state or environment.
determined by house-to-house and room captures. These authors also apply the term *anopheline infective ratio* to the sporozoite-rate expressed as a ratio. The term *transmission-rate* is sometimes employed, and is defined as the number of infections inoculated per unit of time per 100 persons.

**Terms Applied to Methods of Control Directed Against the Vector**

Measures directed towards the prevention of malaria in communities are commonly spoken of as *control measures* \(^v\) or *preventive measures*. Control measures carried out against the vector are *mosquito control measures*. Control measures directed towards protection of the community from the bites of anopheles independent of destruction or prevention of breeding of these insects (e.g., by screening or by the use of repellents) constitute *protection* or *protective control measures*. When directed to achieve this end by attracting anopheles to feed on cattle in place of man, such measures constitute *zooprophylaxis*.

When control measures are specifically directed against some one or more species of anopheles known to be the most important vectors concerned in the transmission of malaria in an area, they constitute *species sanitation*, *species control*, or *species eradication*.

Certain terms have come into general use relating to *mosquito control* or *mosquito control measures*. These may be directed against \((a)\) the aquatic stages (*larval control* or *antilarval measures*), and \((b)\) the adult mosquitoes (*adult control* or *anti-imaginal measures*).

It is not within the scope of this report to define the countless terms used in relation to mosquito control.

\(^v\) Such usage is to be distinguished from control used in the scientific sense as a check to deductions from experiments. To avoid ambiguity, control groups or areas in the latter sense are preferably designated *comparison groups* or *areas*.
Part II

GLOSSARY *

* All terms including the word index or rate have been collected under Indices and Rates respectively.
GLOSSARY

A

Acute infestation
   see Infestation

Adult
   see Imago

Adult haunts
   see Day resting-places

AES
   see Average enlarged spleen

Aestivation
   see page 46

Aestivo-autumnal
   see page 14

Age-group
   see page 30

Aggregation of labour (malaria of)
   see page 28

Ague
   Obsolete name for malaria.

Anautogenous
   A term referring to those mosquitos which require a meal of blood before egg-laying.
   see also Autogenous

Androphilic
   see Anthropophilic

Anopheles
   see page 42
Anopheles composition
  Enumeration of the anopheles mosquitos at a given time and place, according to their species, sex, condition, etc.

Anopheles density
  *see* page 47

Anopheles population
  *see* page 47

Anophelism
  The presence of species of anopheles in a locality irrespective of the presence of malaria.

Anthropophilic
  Applied to mosquitos with a tendency to bite man; relative term carrying often the erroneous implication that species exist with a special desire to feed on man. The true condition is the existence of a scale of *host preference*, which varies with the species and locality. The word androphilic, sometimes used, is incorrect, since it refers to males only.

  *see also* Host preference

Asthenoobiosis
  Condition of temporary biological abeyance in an arthropod, resembling the usual effects of hibernation or aestivation, but occurring independently of temperature or humidity as a direct cause.

  *see also* Heterodynamous

Attack
  *see* pages 20-21

Autochthonous
  *see* page 27

Autogenous
  *see* page 46

Average enlarged spleen (AES)
  *see* page 38

Average newborn infection period
  Mean age (in months) at which parasites are first found in the blood of young infants. The period gives a measure of the liability to infection in an area.

  *see also* Transmission index
Average spleen
Mean projection as determined under average enlarged spleen, but considering all individuals in the community — i.e., the sum of measurements is divided by the total number of persons examined in the community whether the spleen is enlarged or not.

see also Average enlarged spleen; Splenometric index

Batch
see page 43

Benign tertian (B.T.)
see page 14

Biocenosis
A self-contained community of mosquitoes occupying a defined territory.

Biotype
A population consisting of individuals unable to form more than one kind of gamete; natural equivalent of the laboratory pure-line stock or strain. Unsuitable term to indicate the recognized forms of the *A. maculipennis* complex.

Blackwater fever
see page 22

Breeding-ground
An area in which numerous breeding-places are found close together. Sometimes incorrectly used as a synonym of breeding-place.

Breeding out
Raising from eggs, larvae, or pupae as distinct from rearing.
see also Reared; page 43

Breeding-places
Those situations where eggs, larvae, and pupae of mosquitoes are found. Breeding-places may be permanent, when they always contain water; or temporary, when liable to dry up; or potential, when dry, or not showing larvae at the time of examination. They may be natural or man-made; the latter are sometimes called artificial.
see also page 43

Bromeliad malaria
Malaria transmitted by species of anopheles breeding in certain Bromeliaceous plants in South America and Trinidad.
C

Cachexia
Clinical term, sometimes used to describe the anaemic state following prolonged malarial infection.
see also page 22

Catching station
A site selected for periodic sampling of the mosquito population of a locality. It may be any place where adult mosquitos rest. Such stations are often used for checking and controlling mosquito populations.

Chromatin
Characteristically staining nuclear material of the parasite or other cells.

Chronic malaria
A term applied to any manifestation of malaria occurring after the termination of the primary attack.
see also page 22

Class
One of the statistical groups into which the individuals in a frequency distribution have been divided (usually on a basis of magnitude) for convenience of tabulation and analysis.

Clinical prophylaxis
see Prophylaxis

Collective prophylaxis
see Prophylaxis

Colony
A self-contained community of mosquitos, maintained in a laboratory for teaching or experimental purposes.

Comparison area or group
see page 48 (footnote y)

Complex
A species of mosquito and all its related forms, e.g., the *A. maculipennis* or *A. punctulatus* complex.

Control
see page 48
Conveyance
   see Transportation

Crepuscular succession
   see page 47

 Crescents
   Macrogametocytes and microgametocytes of *P. falciparum* and *P. reichenowi*.
   see also page 19

Crisis
   In addition to the clinical sense, used in the sense of a peak of parasiteaemia followed by a sudden fall in numbers of parasites due to acquisition of specific immunity.

Critical density
   see page 47

Cryptozoite
   see page 15

Culture
   see Colony

Cure or recovery (clinical, radical, spontaneous, suppressive)
   see page 25

Cytoplasm
   Characteristically staining protoplasm, as distinct from nuclear material, of the parasite or other cells.

D

Day resting-places
   see page 45

Density
   see Anopheles density; Parasite density

Deviation (animal)
   see page 46

Diapause
   A condition of suspended animation in the mosquito, arrest of growth.
Dispersion

*see* page 45

Diurnal resting-places

*see* Day resting-places

Domestic

Species of mosquito which, in the adult and aquatic stages, live in and around human dwellings.

E

Ecdysis

*see* page 43

*see also* Instar

Eclosion

Emergence of the imago from the pupa case; hatching of the larva from the egg.

E-E form

Colloquial expression for *exoerythrocytic parasite*.

Egg

The first stage in the life of the mosquito; includes the ovum with surrounding follicular structures.

*see also* pages 42-43

Emergence

The escape of the adult winged mosquito (*imago*) from the pupa case.

Empty (female mosquitoes)

*see* page 43

*see also* Engorged (female mosquitoes)

Endemic, Endemicity

*see* pages 27-28

Endemy

A condition in which a disease is constantly present in a region. More specifically in relation to malaria, a condition where infection has ceased to be an occasional occurrence and has become conditioned by regular epidemiological laws involving infection and immunity of the community.

*see also* Endemic, Endemicity
Engorged (female mosquitoes)
   Mosquitoes which have just taken a full blood-meal; which are replete
   with blood.
   see also Empty

Epidemic
   see pages 27-28

Epidemic rise, Epidemic figure
   see page 30

Epigamic behaviour
   Mosquito mating behaviour, such as swarming. Secondary behaviour
   pattern as distinct from the primary act of coitus.

Eradication (mosquito)
   The complete destruction of one or more species (species eradication)
   or of all mosquitoes in a given territory.
   see also page 48

Eurygamous, Eurygamy
   Terms applied to male mosquitoes which swarm as a prelude to mating;
   i.e., to species which require a relatively large space, for example, several
   cubic metres, for mating.
   see also Stenogamous; page 46

Exflagellation
   The formation and extrusion of male gametes by male gametocytes
   occurring in the midgut of mosquitoes, and in artificial media, but never
   in the living vertebrate host.
   see also page 19

Exoerythrocytic (stages of parasite)
   see page 15

F

Falciparum
   see page 15

Fat-body
   Protein reserves laid down by the female mosquito during hibernation
   as a chief store of nutrient.

Fed (female mosquitoes)
   see Engorged
Feeding-places
The rooms, stables, or other places, where female mosquitoes obtain their blood-meal.

Flight, Flight range, Effective flight range
see page 45

G

Gamete
Mature sexual form of malaria parasite (macrogamete and microgamete) occurring in the body of the invertebrate host.

Gametocyte
see page 19

Gametocyte carrier
An individual in whom gametocytes are present and who may thus be infective to anophelines.

Gonotrophic cycle
see page 44

Gonotrophic dissociation
see pages 44, 46
see also Diapause; Hibernation

Gorged
see Engorged

Gravid (female mosquitoes)
Mosquitoes with developed ovaries.

H

Habitat
The locality, large or small, in which a particular mosquito lives; the place where the mosquito is found; haunt.

Habitation
A term used to include any structure normally occupied by man, as distinct from shelter and stable.
Haemoglobin survey
A survey of the degree of anaemia in a group, frequently made in the course of a parasite survey.
see also page 31

Haemoproteus
Generic name (Kruse, 1890) given to certain parasites of birds and reptiles; Halteridium of older writers.
see also page 11 (footnote a)

Haemozoin
see page 19

Hatching
Emergence of the larva from the egg.

Hepatocystis
Generic name (Levaditi & Schoen, 1932) for certain blood parasites of vertebrates, until recently included in the genus Plasmodium, e.g., H. kochi of African monkeys.
see also page 11 (footnote a)

Heterodynamic
Applied to species of which one of the generations of the life-history cycle exhibits asthenobiosis. Species not showing such a condition are homodynamic.
see also Asthenobiosis

Heterologous (strain)
see page 23

Hibernation (complete, partial)
see page 46

Holoendemic
see page 27 (footnote p)

Homodynamic
see Heterodynamic

Homologous (strain)
see page 23
Host

A parasitized or fed-upon organism; parasitized red cell; mammalian species from which anopheles obtain blood.

Host preference, Host of predilection

see page 45

Human blood ratio

see page 45

Hyperendemic

see page 27 (footnote p)

Hypoendemic

see page 27 (footnote p)

Imago

Correct entomological name for the completely developed stage of the mosquito, often termed adult. Plural: imagines.

Imagocide

Agent designed for the purpose of killing adult mosquitoes.

Immune infestation

see Infestation

Immunity

see pages 23-24

Imported malaria

see page 27

Incidence

see page 28

Incubation period

Clinical term designating the period of latency between the initial infection and the first clinical effects, arbitrarily fixed as the first time oral temperature rises to 100°F (37.8°C).

see also Latency; Prepatent period

Index

see page 29

see also Indices
Indices:

Aggregate malaria —
That percentage of persons in the sample examined who have either palpable spleens or positive blood-smears or both; endemic index of Ross.

Anaemia —
Defined by Barber as the degree of polychromatophilia or basophilia as estimated by the number of blue-staining erythrocytes per thick-film field.

Anthropophilic —
see page 45; this index is called natural when derived from wild-caught mosquitoes and experimental when from those laboratory-bred or reared.

Blood —
The blood index is the parasite-rate.
see also Parasite-rate

Blood preference —
Refers to the anthropophilic and zoophilic indices.
see also Anthropophilic Index; Zoophilic Index

Endemic —
The endemic index of Stephens & Christophers is the parasite-rate; that of Ross is the percentage of children showing either parasites or enlargement of spleen or both, i.e., the aggregate malaria index.
see also pages 39-41

Fertilization —
An index derived from the percentage of females of a given species which are found to have spermatozoa in the spermathecae.

Fever —
The percentage of persons in a community who have been ascertained to have had malarial fever during a given period (Ross 23).

Host preference —
The anthropophilic and zoophilic indices are sometimes referred to as host preference indices.
see also page 45

Infection —
see Infection-rate; the term infection index is also sometimes used for the percentage of female mosquitoes found with oocysts or sporozoites or both; it may be an experimental or a natural index.
Indices: (continued)

Infective density —

The product obtained by multiplying the mean daily anopheline density per room searched by the quotient secured from dividing the number found there with gland infection by the number dissected (Davey & Gordon?). The formula given by these two authors is as follows:

\[
\frac{\text{Total number of female anophelines captured} + x \times \text{Total number of rooms examined}}{\text{Total number of sporozoite-infected anophelines dissected}}
\]

* \(x = \) number of anophelines which left before the time of examination (early mornings) of the houses.

Infestation —

The average positive parasite-count is sometimes called the infestation index.

Inoculation risk —

The figure obtained when (a) the value for the mean number of infected anophelines per house is divided by the assumed frequency of nocturnal feeding, and (b) this quotient is further divided by the mean of the number of occupants per house.

Macdonald’s —

This index is the proportion of those children with enlarged spleen who show parasites on microscopical examination.

see also page 41

Malaria —

The malaria index and the aggregate malaria index are the same.

see also Aggregate malaria index

Maxillary —

The mean number of teeth on the maxilla of female mosquitoes.

Oocyst —

see Oocyst rate

Ovarian —

The percentage of mosquitoes in any given lot showing ovaries in stage 1.
Indices: (continued)

**Palpal** —

The ratio of the length of the fifth segment of the palp to that of the fourth is sometimes called the *palpal index*.

**Parasite, Parasitic** —

*see* Parasite-rate

**Ross** —

The average enlarged spleen has sometimes been called the *Ross index*.

**Spleen, Splenic** —

*see* Spleen-rate

**Splenometric** —

*see* page 40

**Sporozoite** —

*see* Sporozoite-rate

**Transmission** —

*see* page 41

*see also* Transmission-rate

**Zoophilic** —

*see* page 45

**Indigenous (malaria)**

*see* page 27

**Indigenous (mosquito)**

A species of mosquito occurring naturally in an area, as distinct from immigrants or invaders.

**Individual prophylaxis**

*see* Prophylaxis

**Induced malaria**

Malaria artificially brought about for the purpose of malariotherapy (or experimentation).

**Infected anopholes**

Female anopholes with oocysts on the gut-wall with or without sporozoites in the salivary glands.

*see also* Infective anopholes
Infection immunity

A refractory condition dependent on an immunity arising from existing infection which prevents further infection following inoculation of a homologous strain. Commonly known as premunition. A condition in which the infection and immunity processes are in balance so that infection may be latent (unaccompanied by clinical or parasitological evidence) at one time and active (during attacks, relapses) at others. Also called concomitant immunity (Sinton 29).

see also Immunity; pages 23-24

Infecive

Capable of giving rise to infection, e.g., a host harbouring gametocytes, or a vector with sporozoites in the glands.

Infecive anopheles

Female anopheles with normal sporozoites in the salivary glands (with or without oocysts on the midgut).

Infecive density

The number of female anopheles found with sporozoites in the salivary glands per standard collecting unit.

see also page 47

Infestation

(1) Term applied to the presence of non-microbic parasites, in contra-distinction to the term infection applied to microbic parasites, e.g., hookworm infestation, malarial infection.

(2) The presence, in a community, of mosquitoes as distinct from the presence of malaria.

(3) Acute: sometimes applied, in a highly endemic area, to an early stage of infection among children who have a high parasitaemia and acute illness.

(4) Immune: stage of infection following acute infestation, characterized by a low parasite density and the development of tolerance.

Infiltration

The progressive invasion of an area by mosquitoes.

see also page 45

Innate (racial, species) immunity

see page 24
Insectary
A room or building specially constructed or adapted for the rearing of mosquitoes or other insects in captivity.

Instar
The period or stage between moults in the larva. The first instar is the stage between the egg and the first moult; then follow the second, third, and fourth instars before the pupa.

see also Ecdysis

Intensity of malaria
If applied with reference to an individual, this term may be used to denote either the severity of symptoms, or the number of parasites per mm$^3$ of blood (parasite-count). If applied to a community, it commonly refers to the morbidity-rate, but more precisely to the parasite density, as against frequency of infection. If applied to liability to contract infection, the term denotes infective density.

see also Transmission index; Transmission-rate

Intermittent, Intermittent stage
see page 21

Intermittent fever
Obsolete name for malaria.

Introduced malaria
see page 27

Isodiagnosis
Inoculation of a known susceptible animal with the blood of another animal to ascertain if the latter is infected; a procedure employed to detect infection otherwise inapparent.

L

Larva
The aquatic stage of growth of the mosquito, occurring between the egg and the pupa.

see also Instar

Larval malaria
see page 22
Larval stages
In mosquitoes there are four larval stages or instars between moults.

*see also Instar*

Larvicide
Any agent used for the destruction of larvae.

Latency, Latent malaria
A condition in which malarial infection is not evidenced clinically by active manifestations or, from the parasitological point of view, when few or no parasites can be detected by microscopical examination. There is normally a latent period preceding the primary attack (*incubation latency*), and also a period or periods of latency following upon the primary attack (*infection latency*). Incubation latency in absence of the primary attack may continue into infection latency. With some strains of *P. vivax* and *P. ovale* the primary attack may be delayed for several months, and the period of latency is then referred to as a *protracted incubation latency* or *period*.

Laverania

*see page 12*

Leucocytozoon
Generic name (Danilewsky, 1890) given to certain blood parasites of birds.

Long-term relapse

*see page 21*

M

Macrogamete

*see page 19*

Macrogametocyte

*see page 19*

Macroschizont

*see page 16*

Malaria
Disease of man caused by various species of the genus *Plasmodium* also commonly applied to similar diseases in animals.

Malaria parasites

*see pages 11-15*
Malaria pigment

Pigment related to, or identical with, a form of haematin occurring in the cytoplasm of erythrocytic forms of malaria parasites, in the organs and tissues following destruction of these parasites, and in the sporogonic cycle, except for the sporozoites.

Malaria therapy

The treatment of certain diseases, notably general paralysis, by infecting the patient with malaria.

see also Induced malaria

Malariae

see pages 12, 13

Malariogenic

Referring to conditions conducive to transmission of malaria.

Malariometry

The application of quantitative measures to the study of malaria.

Malignant tertian (M.T.)

see page 14

Mature schizont

see page 18

Maurer’s spots or clefts

A form of alteration of the red cell consisting of irregular spotting produced by P. falciparum; to be contrasted with the fine even granulations seen with vivax and ovale, Schüffner’s dots.

see also page 20

Mean parasite-count

see page 33

Mean positive parasite-count

see page 33

Merozoite

see page 18

Mesoendemic

see page 27 (footnote p)

Metacryptozoite

see page 15
Metaxenous parasite

A parasite spending part of its life in one kind of host, and the rest of it in one or several others.

Microclimate

*see* page 46

Microgamete

*see* page 19

Microgametocyte

*see* page 19

Microschizont

*see* page 16

Midgut

Part of the alimentary tract of the mosquito between the fore- and hind-gut, i.e., the stomach.

Moult

To cast off the skin periodically, as in the larva of the mosquito in the process of growing (*ecdysis*); sometimes used of the cast skin itself (*pelt*).

Moultmg

*see* Ecdysis

Multiparous (mosquitos)

Female mosquitoes which have oviposited one or more times.

*see also* page 44

N

Nightly efflux

The number of mosquitoes leaving a feeding- or resting-place nightly, e.g., for oviposition.

*see also* page 47

Nightly influx

The number of mosquitoes newly arriving at a feeding- or resting-place; newly emerged entrants are referred to as the *newcomer influx*.

*see also* page 47
Nightly turnover
    Changes in distribution of mosquitos which take place each night, owing to efflux, influx, and death.
    see also page 47

Nulliparous (mosquitos)
    Female mosquitos which have not laid eggs.
    see also page 44

Nuptial dance
    see Swarming
    see also page 46

O

Occult segmentation
    Erythrocytic schizogony of *P. falciparum* elsewhere than in the peripheral blood.

Oocyst
    see page 20

Ookinete
    see page 20

Outdoor resting-places
    Cracks and crevices in the earth, caves, hollow trees, and similar places where mosquitos rest, as distinct from houses, stables, pigsties, etc.

Output
    The number of adult mosquitos produced from a breeding-place or area per unit of time.

Ovale
    see page 13

Ovarian stages
    see page 43

Overt attack
    see page 21

Overwintering
    Short periods of inactivity during the winter without actual hibernation, not necessarily in the adult stage; some mosquitos pass the winter as larvae in which the rate of development has slowed down.
    see also page 46
Parasite asymptote
   *see* page 34

Parasite density
   *see* page 33

Parasite formula
   *see* page 35

Parasite frequency distribution
   *see* page 34

Parasite survey
   *see* page 32

Parasitic relapse
   *see* page 23

Paroxysm
   *see* page 21

Passive dispersion or dispersal
   *see* page 45

Patent period
   Period during which parasites are demonstrable in the peripheral blood on microscopical examination.

Pelt
   *see* Moult

Periodicity
   *see* page 21

Pernicosa
   *see* page 14

Phanerozoite
   *see* page 15

Plasmodium
   *see* pages 11-15
Post-epidemic hyperendemicity

A term sometimes applied to enhanced endemicity following upon an epidemic.

Praecox

see page 12

Precipitin test

A test applied to the undigested blood taken from the midgut of a recently-caught female mosquito. In its simplest form the test can indicate what proportion of the insects give a reaction positive for human blood. Specific sera reacting to the blood of a range of common animals are often used.

Pre-erythrocytic

see page 15

Prehibernation flight

A dispersion of mosquitoes that occurs in some species of anopheles before hibernation. This type of dispersion is often to distances greater than the normal and is sometimes called long distance dispersion.

Premunition

see page 24

see also Infection immunity

Prepatent period

see page 22

Prevalence of malaria

see page 28

Preventive treatment

see pages 25-26

Primary attack

see pages 20, 21 (footnote n)

Prophylaxis

see pages 25-26, 48

Proteosoma

Generic name (Labbé, 1894) formerly applied to a plasmodium in birds: *P. relictum* (Grassi & Feletti, 1892).
Protracted incubation latency or period
   *see* Latency

Pupa
   The stage between the larva and the imago in the development of the mosquito, when it is aquatic and active but does not feed.

Pupation
   The process of becoming a pupa, at which time the fourth and last larval skin is cast.

Q

Quartan
   *see* pages 14, 22

R

Race
   A form of a species of mosquito with constant morphological or biological characters in one or more stages.

Radical cure
   *see* page 25

Rate
   *see* page 29
   *see also* Rates

Rates:

Absolute parasite —
   Synonymous with *true* infection-rate.
   *see also* Infection-rate

All-species infection —
   *see* Infection-rate

Annual attack —
   The number of individuals per thousand found infected with malaria per year in a community.

Biting —
   The proportion of female mosquitoes caught biting on a bait at certain stated times during the twenty-four hours.
Rates: (continued)

Constantly sick —

The average proportion of people who are actually ill with malarial fever at a given moment is the *constantly sick rate* but the number found to be ill is the *constantly sick index*.

Death —

*see* Mortality-rate

Fertilization —

*see* Fertilization index

Infant parasite —

*see* page 41

Infectivity —

The percentage of female anopheles mosquitos found by dissection to contain the parasites of malaria either as sporozoites in the salivary glands or as oocysts on the gut-wall; determined for each species of anopheles separately.

*see also* Oocyst-rate; Sporozoite-rate

Infection —

The actual number of persons infected, which is the *true infection-rate* or *absolute parasite-rate*. The *all-species infection-rate* is the number of separate infections found by microscopic examination per 100 persons in a community, counting infections by each species of parasite separately; may be over 100. The percentage of total infections which are due to a given species of parasite is the infection-rate for that species.

*see also* page 35

Inoculation —

The proportion of a population receiving infective inocula in a given unit of time.

Malaria —

The *true infection-rate*.

*see also* Infection-rate; page 35

Morbidity —

*see* page 29

Mortality —

*see* page 29

Oocyst —

*see* page 47
Rates: (continued)

Parasite, Parasitic —

see page 31

Relapse —

see pages 21, 23

Species infection —

see page 35

Spleen, Splenic —

see pages 35-37

Sporozoite —

see page 47

Transmission —

see page 48

see also Transmission index

True infection —

see Infection-rate

Ratio

see page 29

Reared

Applied to the mosquito at any stage of its life-history when it is derived from a colony maintained in the laboratory.

see also page 43

Recession, Regression

Disappearance, due to natural causes, of malaria in certain temperate regions.

Recrudescence

see page 21 (footnote m)

Recurrence

see page 21 (footnote m)

Regional epidemics

see page 28

Regression

see Recession
Reinfection
Recurrence of infection after the original infection has died out or has been eliminated by treatment.

Relapse
*see* pages 21, 23

Relative prevalence
*see* page 35

Remittent
*see* page 21

Resistance, Resistant
A term used with reference to the tolerance of:
(1) plasmodia to the action of certain drugs;
(2) insects to the action of certain insecticides:
   
   (a) *resistance* — ability, transmissible from one generation to another, of a population of insects to withstand a toxicant to a greater degree than normal. Resistance may be: (i) *physiological* — ability through physiological processes to withstand toxicants which have entered the body; (ii) *morphological* — ability to prevent the toxicant from entering the body; (iii) *behaviouristic* — ability to avoid contact with a toxicant by behaviouristic action;

   (b) *tolerance* — ability of the individual insect to withstand normally fatal doses of a toxicant because it has previously been exposed to sublethal doses of the same or a closely related toxicant;

(3) man to malaria parasites.
*see also* pages 23, 24

Resting-places
*see* pages 45, 46

Ring forms
*see* page 18 (footnote j)

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S

Salivary glands
Two glands situated in the forepart of the thorax of the mosquito above the first pair of legs; each gland has three lobes.
Schizogonic period
The time taken by any species of parasite to complete its schizogonic cycle.

see also pages 15-19

Schizogony, Schizont

see pages 15, 16

Schöffner’s dots
Fine, evenly distributed granulations brought out by suitable staining in red cells infected with P. vivax and P. ovale.

see also Maurer’s spots; page 20

Seasonal epidemic

see page 28

Segmentation

see page 18

Segmenter

see page 18

Semihibernation

see Hibernation (partial)

see also page 46

Sequelae

see page 22

Shelters

see page 46

Short-term relapse

see page 21

Simple tertian

see page 14

Species
In general and rather loose terms: an aggregation of individuals, alike in some constant character or characters, which mate freely and produce young which themselves mate and bear fertile offspring resembling each other and their parents.

see also page 42
Species control
  *see* page 48

Species eradication
  *see* Eradication

Species sanitation
  *see* page 48

Spleen, size of
  *see* pages 35-39

Splen
  The mean increase in splenic substance resulting from a single untreated infection in a child of 2-9 years of age.

Spontaneous recovery
  *see* page 25

Sporadic malaria
  *see* page 27

Sporogony
  Sexual phase of the life-cycle.

Sporozoite
  *see* page 20

Stable
  Any form of artificial structure in which animals are kept—e.g., horse stables, cattle sheds, pigsties—as distinct from human habitations.

Static malaria
  *see* page 40 (footnote ν)

Stenogamous, Stenogamy
  Terms applied to male mosquitoes which will mate in a confined space, e.g., a small cage.
  *see also* Eurygamous; page 46

Stippling
  *see* page 20
Subpatent period
A period when malaria parasites are not detectable in the blood by microscopic examination; parasitic latency.

Subspecies
see page 42

Subtertian
see page 14

Superinfection
A fresh infection produced in an animal already infected with the same organism. Strictly, a superinfection can occur only if the second strain used is heterologous to that causing the original infection, but a small (parasitic) relapse may occur as a result of a subsequent homologous superinfection.
see also page 23

Suppression, Suppressive treatment
see page 25

Swarming
The nuptial flight or dance when males of some species of mosquito gather together on the wing, usually at dusk or in dim light, in the open, moving up and down in the air without making any progress. In such species the females fly into the swarm of males and copulation takes place in the air.
see also Eurygamous; page 46

T

Taxis
Impulses of a reflex character which follow certain stimuli in insects. The term tropism is used in this sense.

Tenue
Specific name (Stephens, 1914) given to a parasite resembling P. falciparum; now regarded as a synonym.

Tissue phase or stage of plasmodium
see page 15

Tolerance
see Resistance
Transportation
Passive dispersion of anopheles by vehicles—train, ship, aircraft, etc.; sometimes termed conveyance.
see also page 45

Trophozoite
see pages 15, 19

Tropica
see page 14

Tropical aggregation (of labour)
see Aggregation of labour

Tropism
see Taxis

True causal prophylaxis
see Prophylaxis

V

Vacuole
The clear space seen in ring forms and sometimes in larger parasites.

Vector of malaria
A species of mosquito in which the plasmodium completes its sexual cycle in nature.

Vivax
see pages 13, 14

W

Wild
A term applied to those species of mosquito which normally live entirely out-of-doors and never enter human dwellings.

Wind dispersion
see page 45
Z

Ziemann's stippling
  see page 20

Zoophilic
  see pages 45-46
  see also Zoophilic index

Zooprophylyaxis
  see page 48

Zygote
  see page 20
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