TERMINOLOGY OF MALARIA
AND OF
MALARIA ERADICATION

Report of a Drafting Committee

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INTRODUCTION

Medical language must be adaptable so that it can keep pace with the constant increase of our knowledge and with the continual revision and evolution of our concepts. All the various branches of medicine have developed their own vocabularies, which are often fully understood only by those who commonly use them. During recent times terminology has grown more complicated through the introduction of terms contributed by the sciences on which medicine generally and public health in particular increasingly depend. Although this development is inevitable, it has its dangers, since it tends to turn the specialties into closed cults. Every new practitioner of a specialty has to go through a period of initiation in which the terms must be mastered and fully understood. The development of terms cannot be wholly rational, since some persist even after the ideas they originally represented have become obsolete. Retention of such terms is justifiable only when their new meanings are quite clear. The more accurate our use of words, the clearer is the understanding of what we mean.

As early as the 1930's there was a need for standardization of terminology in malaria. The Malaria Commission of the League of Nations compiled the first report on terminology in malaria, which was published in 1940 in the Bulletin of the Health Organisation of the League of Nations. This report was prepared in English and French by a sub-committee consisting of Sir Rickard Christophers, Dr L. W. Hackett, Professor Edmond Sergent, Professor W. Schülter and Dr E. J. Pampana, the Secretary of the Malaria Commission. It provided a French-English glossary of 250 terms and was of substantial value in the development of malariology, since it brought some order into the previous confusion.

During the ten years that followed the appearance of the first report on terminology in malaria, the development of malaria research and the world-wide expansion of successful methods of malaria control were so rapid that in 1949 the Expert Committee on Malaria of the World Health Organization recommended the appointment by the World Health Organization of a new Drafting Committee to revise the first report and bring it up to date. After this Committee had completed its task of preparing an English edition of Malaria Terminology (Covell, Russell & Swellengrebel, 1953), a parallel Drafting Committee was entrusted with the preparation of the French text, Terminologie du Paludisme (Vaucel, Roubaud & Galliard, 1954). The French text followed the general lines of the English edition of
Malaria Terminology but took into account many substantial differences between the French and the Anglo-American practice of malariology and expanded, to some extent, the scope of its report.

The need for a new terminology of malaria has been increasingly felt by all malaria workers during recent years, mainly because of the almost world-wide conversion from malaria control to malaria eradication and the consequent introduction of a whole series of new epidemiological and operational concepts and terms. Each of the last four sessions of the WHO Expert Committee on Malaria (1957, 1959, 1961, 1962) has resulted in the creation of new ideas and expressions pertaining to activities connected with the new strategy. The Eighth Report of the WHO Expert Committee on Malaria (1961) recommended that all these concepts should be defined and standardized and that a new Drafting Committee should be appointed to bring the terminology of malaria up to date and to include all the terms necessary in malaria eradication programmes.

The present publication represents the result of work carried out by four members of the WHO Expert Advisory Panel on Malaria appointed by the Director-General and assisted by the Secretariat of the Organization. The task of the Drafting Committee was of considerable complexity. The work covers many fields which were not included in the previous publications; all of them have a bearing on the many-sided activities of malaria eradication. While its forerunners dealt with the parasitology, epidemiology, entomology and chemotherapy related to malaria, this volume is the first to cover the fields of the theory and practice of malaria eradication. Epidemiological concepts and problems which were previously of only academic interest have now become of operational importance and need full attention and precise terminology. (See Pampana, 1963.)

As in the previous Malaria Terminology and Terminologie du Paludisme, the Glossary is preceded by a text in which the fundamental concepts pertaining to well-defined fields of malariology and of malaria eradication are grouped and discussed in some detail. In addition to the new sections on malaria eradication, another is devoted to the essentials of zoological classification and nomenclature.

While the aim of the Drafting Committee was to prepare a comprehensive and instructive publication, it was also desirable to avoid overburdening the Glossary with too many terms. The Committee therefore decided to omit some terms whose definition can easily be found in medical or other dictionaries, so as not to expand the present publication beyond its strict terms of reference. The size of the Glossary has nevertheless increased, reflecting the extension of the scope of malaria eradication.

The Drafting Committee is aware that this Terminology has shortcomings, and that terminologies are never quite complete, no matter how much time is spent on their compilation. Nevertheless, it is hoped that the present
one will clarify much that had become ambiguous or inaccurate and that it will establish clearly the meaning of some new terms. In such a condensed work there is space for only the most important references; the more aspiring reader should consult such monumental works as Boyd (1949) or Russell et al. (1946; new edition in press).

This publication has no more ambitious purpose than to be a useful tool for medical practitioners, parasitologists, entomologists, public health administrators, sanitary engineers, public health educators, biologists, social workers and all the others concerned with problems of malaria generally; and particularly for those working in various fields related to malaria eradication.

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The Drafting Committee wishes to acknowledge the valuable comments of the late Professor W. N. Beklemishev, of Professor D. S. Bertram, Dr R. S. Bray, Sir Rickard Christophers, Dr R. G. Coatney, Mr G. Davidson, Mr R. Elliott, Dr C. A. Hoare, Dr Clay Huff, Mr P. F. Mattingly, Dr L. Parrot, Professor P. G. Sergiev, the late Dr S. Swaroop, and Médecin Général M. Vaucel; of the Malaria Advisers to the Regional Offices of WHO; and of the staff of the WHO Division of Environmental Health.

A first draft of the Glossary, used by the Drafting Committee as their working document, was prepared by the Division of Malaria Eradication of the World Health Organization. The members of the Drafting Committee gladly acknowledge their debt of gratitude for the preparation of this basic document and for all the assistance received.
I. MALARIA PARASITES AND THE INFECTIONS

THEY CAUSE

The name "malaria"

1. 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 in, for example, the English, German, Italian and Russian languages, and paludisme and paludismo in the French and Spanish, respectively. (In the latter two languages "malaria" is also sometimes employed.)

Although these names are indicative of more or less mistaken conceptions of the true causation of the disease, there is no urgent need for a more appropriate name; it would, however, be proper to refer to plasmodial infections as plasmodiose.

The malaria parasites

2. The organisms causing malaria are commonly referred to collectively as malaria parasites. The term "malaria parasite" is best restricted to those organisms belonging to the family Plasmodiidae, but even today, as in the past, some authors use it to refer to other parasites of the order Haemosporidia, particularly various pigmented parasites found in the blood of birds or mammals. True malaria parasites multiply in the blood stream, causing fever and stimulating immunity; the others do not multiply in the blood stream and they cause probably no fever and little or no immunity. The present taxonomic status of the Haemosporidia is as follows:

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1 Although these two names are widely employed in the Indo-European family of languages in a generic sense, the following equivalents are also occasionally used: Wicchelfieber (German), chêu (Polish), kald-fieber (Danish and Norwegian), يتم (Turkish), kadakhaz (Hebrew), chémia (Greek). In Portuguese writings the names malária and sepaulismo are sometimes employed. The obsolete English name "aqua", used by Cluver in 1396, was originally employed for any acute fever, but in the 17th and 18th centuries it was more specifically applied to intermittent fevers commonly due to malaria (Russell, 1955).

2 Malária: "bad air"; paludisme: "coming from the marshes".

The concept of malaria as a single morbid process or disease, and certainly the use of the term "malaria", are of relatively late origin. Torri (1658-1741), who first definitely distinguished malaria from other fevers through their property of being cured by cinchona bark, does not employ the term "malaria" or any single term synonymous with it in his famous work "Therapeutica Specialis", first published in 1712. According to the Oxford English Dictionary, the word "malaria" was first used in general literature by Horace Walpole in 1740 to describe the fevers in Rome. John Macculloch, in Malaria: An Essay on the Production and Propagation of This Fever (1829), was the first English medical writer to use this name, which he borrowed from Italy. "Malaria" was first used more in the sense of the condition or conditions responsible for the causation of the miasmatic fevers than to designate the disease itself. Later it seems to have acquired a clinical and eventually a parasitological significance in the natural course of evolution of the term. In epidemiology there is often some return to its use in a general sense as designating a condition not wholly confined to human infection, that is, conveying the idea of prevalence of the parasite in man and mosquito in an area.

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11
3. The family Plasmodiidae may be defined as including those parasites which undergo two types of schizogony (exoerythrocytic and pigment-producing erythrocytic) in the vertebrate host and a sexual phase followed by sporogony in the mosquito host. In the genus *Plasmodium*, the exoerythrocytic schizont occurs in multiple generations in the parenchymal cells of the liver with the production of 1000 or more merozoites, the gametocytes are round, and the mosquito host is a species of *Anopheles*. In the genus *Laverania*, which comprises *L. falcipara* and *L. reichenowi*, the exoerythrocytic schizont occurs for one generation only in the parenchymal cells of the liver with the production of 10,000 or more merozoites, the gametocytes are crescentic, and the mosquito host is a species of *Anopheles*. In the genus *Haemamoeba*, the exoerythrocytic schizont occurs in mesodermal cells with the production of 1000 or fewer merozoites, the gametocytes are either round or crescentic, and the mosquito host is usually a species other than *Anopheles*. This genus comprises avian and reptilian parasites only.\(^1\)

4. The family Haemoproteidae may be defined as including those parasites which undergo one type of schizogony (exoerythrocytic) in the vertebrate host, followed by gametocytophagy (pigmented) in the erythrocytes, and finally sporogony in an arthropod probably other than a mosquito. *Hepatocystis* occurs in monkeys and other animals, *Nycteris* and *Polychromophilus* in bats, and *Haemoproteus* in birds and reptiles. They are not further defined here.

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\(^1\) It has recently been proposed (Garnham, personal communication) to use four subgeneric names for the avian malaria parasites within the genus *Plasmodium*, and such treatment seems likely to be extended to the mammalian and squamate parasites. In this way the conventional terms *Plasmodium falciparum* or *Plasmodium gallinaceum* will be preserved for general use and the appropriate subgenera employed for special purposes.
5. The family Leucocytozoidea may be defined as including those parasites which undergo one type of schizogony (exoerythrocytic) in the vertebrate host, followed by gametocytophagny without true pigment in blood cells, and finally sporogony in certain black flies (Simuliidae). The single genus known at present is confined to birds.

6. The simple distinction between these families is the presence of schizonts and gametocytes in the blood in the Plasmodiidae and the presence of gametocytes only in the blood in the Haemoproteidae; the former are transmitted by mosquitoes, the latter by other Diptera (e.g., Culicoides, Simulium). Leucocytozoidea are distinguished from these other families by the absence of true pigment in any stage of the life cycle.

7. The question of the correctness of the specific names of the human malaria parasites and particularly of the malignant tertian parasite is complicated. The controversy has been concerned chiefly with the question of whether the correct name of this species is *praecox, immaculatum*, or *falciparum*. Grassi & Feletti (1890) believed that certain parasites (*Protozoa*) 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—and gave to both these parasites the name *praecox*. Those who hold that the authors gave the 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 in the first description, so that *praecox* cannot be valid for the human parasite, and that the correct name for the latter 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 believe to be the first valid name.

Actually, the position is even more difficult than this, since Laveran's specific name *malariae* is undoubtedly valid as applied to the malignant tertian parasite, which he clearly described, while the name *malariae* given by Grassi & Feletti to the quarten parasite was not intended, as assumed by many later writers, to displace Laveran's name but was applied by them to a species in another genus (*Haemamoeba*). In other words, there were two species with the same specific name, but in two different genera: *Laverania malariae* Laveran, 1881 (the malignant tertian parasite), and *Haemamoeba malariae* Grassi & Feletti, 1890 (the quarten parasite). Both names are perfectly valid so long as the names of the two 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.¹

8. The International Commission on Zoological Nomenclature (see Chap. VII) gave two important decisions on the names of the human malaria parasites. The earlier, in 1928, was expressed in Opinion 104; it has been superseded by Opinion 283, issued in 1954 after lengthy circulation of the question to malariologists and zoologists. The latter Opinion declared that: "...the trivial name *vivax* Grassi & Feletti, 1890, as published in the combination *Haemamoeba vivax*, is the oldest available trivial name for, and therefore the valid trivial name of, the Benign Tertian Malaria Parasite" and substituted the following particulars in regard to the generic names *Plasmodium* and *Laverania* in the *Official List of Generic Names in Zoology* in place of the particulars deleted:

"(a) *Plasmodium* Marchiafava & Celli, 1885 (type species by designation under the Plenary Powers: *Haemamoeba malariae* Feletti & Grassi, 1889) (the Quartan Malaria Parasite);

(b) *Laverania* Feletti & Grassi, 1889 (type species by designation under the Plenary Powers: *Haematozoon falciparum* Welch, 1897) (the Malignant Tertian Malaria Parasite) [generic name to be used by authors who consider the Malignant Tertian (or Aestivo-Autumnal) Malaria Parasite to be generically distinct from the Quartan Malaria Parasite]."

9. The correct names of the human malaria parasites, according to whether one genus only or two genera are recognized on taxonomic grounds, are as follows:

If only one genus is recognized:

- *Plasmodium malariae* (Laveran, 1881)
- *Plasmodium vivax* (Grassi & Feletti, 1890)²
- *Plasmodium falciparum* Welch, 1897
- *Plasmodium ovale* Stephens, 1922

If two genera are recognized:

- *Plasmodium malariae* (Laveran, 1881)
- *Plasmodium vivax* (Grassi & Feletti, 1890)
- *Laverania falcipara* (Welch, 1897)
- *Plasmodium ovale* Stephens, 1922

In this listing, the names of the four species of human malaria parasites are given in full, including the author and the year of description. As

¹ For a complete summary of the position, see: Sergent et al. (1929), Christopher & Sinton (1938, 1939), and Sergent et al. (1939).

² The *P. vivax* of north-eastern Europe, responsible for infections with a protracted incubation period, was given the subspecific name of *P. vivax siberiana* by Nikolaiev in 1949.
explained in Chapter VII, the author’s name follows the specific name without punctuation; the year of publication is separated by a comma. Parentheses around the author’s name and year indicate that the species was originally described under another generic name. They are therefore correctly used in *P. vivax* (Grassi & Feletti, 1890), since this species was originally described as *Haemamoeba vivax*, but are not needed in *P. falciparum* Welch, 1897. On the other hand, if the name *Laverania falcipara* is used, the author’s name and date must be given in parentheses to indicate the change of the original name of the parasite.

The International Commission on Zoological Nomenclature expressed no preference for the use of either generic name for the malignant tertian parasite and left the choice to zoologists according to whether or not they believe that two genera are required. Consequently either name can be used without violating the rules of zoological nomenclature.

The two principal arguments for the use of *L. falcipara* are (1) the distinctive shape of the gametocytes and (2) the existence of a single generation of exoerythrocytic schizogony, which phylogenetically removes this genus still farther from its presumed coccidial ancestor. These arguments appear valid, and in a zoological context, the use of *Laverania* is recommended; in malariology, the rejection of the familiar *Plasmodium* might be disturbing, and, as its use is still taxonomically permissible, it appears preferable to retain *Plasmodium* in this Terminology.

10. A number of colloquial names have been applied to the infections caused by the various human *Plasmodium* species, as follows:

<table>
<thead>
<tr>
<th>Name of parasite</th>
<th>Colloquial name</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>P. vivax</em></td>
<td>Benign tertian</td>
</tr>
<tr>
<td></td>
<td>Simple tertian</td>
</tr>
<tr>
<td></td>
<td>Tertian</td>
</tr>
<tr>
<td><em>P. malariae</em></td>
<td>Quartan</td>
</tr>
<tr>
<td><em>P. falciparum</em></td>
<td>Malignant tertian</td>
</tr>
<tr>
<td></td>
<td>Aestivo-autumnal</td>
</tr>
<tr>
<td></td>
<td>Subtertian</td>
</tr>
<tr>
<td></td>
<td>Malignant</td>
</tr>
<tr>
<td></td>
<td>Tropical, malaria tropica</td>
</tr>
<tr>
<td></td>
<td>Pernicious, malaria perniciosa</td>
</tr>
</tbody>
</table>

These colloquial names are becoming obsolete. Their replacement by the unitalicized specific names of the plasmodia concerned—e.g., vivax malaria, falciparum infection—is recommended. An exception may be made with regard to “malariae” as this is likely to cause confusion; a term such as “quartan relapse” is acceptable.
Forms of the parasite in the vertebrate host

11. In the vertebrate host, following inoculation of sporozoites, there is a short period of about half an hour when the blood is infective if large quantities are inoculated into another organism. This is followed by a period during which no parasites can be found and the blood is non-infective. The duration of this prepatent period varies according to parasite species 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. The length of the prepatent period and the morphology of these tissue stages are characteristic for each species; the main features are given in the accompanying table.

<table>
<thead>
<tr>
<th>Species of parasite</th>
<th>Duration of primary exoerythrocytic schizogony, in days</th>
<th>Approximate size of mature schizont, in microns</th>
<th>Approximate number of merozoites</th>
<th>Size of merozoites, in microns</th>
<th>Special features</th>
<th>Secondary exoerythrocytic schizogony</th>
</tr>
</thead>
<tbody>
<tr>
<td>P. cynomolgi</td>
<td>8</td>
<td>40 under 10 000</td>
<td>1.2</td>
<td>Vacuoles</td>
<td>Present</td>
<td>Probable</td>
</tr>
<tr>
<td>P. cynomolgi bastianelli</td>
<td>7</td>
<td>30 under 10 000</td>
<td>1.2</td>
<td>No vacuoles</td>
<td>Present</td>
<td>Improbable</td>
</tr>
<tr>
<td>P. vivax</td>
<td>8</td>
<td>45 over 10 000</td>
<td>1.2</td>
<td>Vacuoles</td>
<td>Present</td>
<td>Improbable</td>
</tr>
<tr>
<td>P. falciparum</td>
<td>5%</td>
<td>60 40 000</td>
<td>0.7</td>
<td>Small nuclei, cytomeres</td>
<td>Present</td>
<td>Probable</td>
</tr>
<tr>
<td>P. inui (quartan)</td>
<td>11</td>
<td>25 2 000</td>
<td>1.0</td>
<td>Cytomeres, enlarged host cell nucleus</td>
<td>Present</td>
<td>Probable</td>
</tr>
<tr>
<td>P. malaris (quartan)</td>
<td>12-16 (7)</td>
<td>45 ?</td>
<td>?</td>
<td>Enlarged host cell nucleus</td>
<td>Probable</td>
<td>Probable</td>
</tr>
<tr>
<td>P. ovale</td>
<td>9</td>
<td>70 15 000</td>
<td>1.8</td>
<td>Large nuclei, flocculi</td>
<td>Present</td>
<td>Probable</td>
</tr>
<tr>
<td>P. knowlesi</td>
<td>5%</td>
<td>40 ?</td>
<td>1.2</td>
<td></td>
<td></td>
<td>Probable</td>
</tr>
</tbody>
</table>

* Modified from Garnham (1958).

It is zoologically correct but may be confusing to refer to man or animals as the intermediate host of human malaria; it is preferable to speak of the vertebrate host. The part of the life-cycle of the plasmodium occurring in the vertebrate host is often referred to as the intrinsic phase.

12. Exoerythrocytic stages (tissue stages) are all those stages of the malaria parasite which are found in cells of the vertebrate host other than
the red blood cells. It is necessary to distinguish between the primary tissue stages and the secondary tissue stages arising from later forms of the parasite. The primary exoerythrocytic schizogony represents the development of the sporozoite; the secondary exoerythrocytic schizogonies are subsequent stages which are partly responsible for the continuation of the infection and are the cause of relapses.

On the basis chiefly of observations in avian malaria it appears that subsequent to the sporozoite infection of the vertebrate host cell, cryptozoic schizogony \textsuperscript{1} takes place. Cryptozoic merozoites ("cryptozoites") produced from cryptozoic schizonts may enter other fixed cells initiating further schizogony, giving rise to the second generation of metacryptozoic schizonts (Huff and Coulston, 1944; Bray, 1957). Cryptozoic and metacryptozoic schizogonies occur before the appearance of parasites in the blood, and the whole of this period is known as the pre-erythrocytic or primary tissue stage.

Some of the metacryptozoites liberated from the metacryptozoic schizonts penetrate the red blood cells and start the erythrocytic schizogony. But others may remain in the fixed cells or invade new ones and thus initiate secondary tissue stages. The tissue forms of the parasite subsequent to the appearance of erythrocytic parasites are sometimes known as phanerozoites. (These terms are largely limited to avian malaria.)

The course of exoerythrocytic schizogony follows seven principal types (Fig. 1). These types are: I, elongatum; II, gallinaceum; III, mexicanum; IV, cynomolgi; V, falciparum; VI, murinum; VII, kochi. For the gallinaceum, elongatum and mexicanum types there is an interchange between blood and tissue, so that in these types, tissue stages may arise following blood inoculations. However, in the gallinaceum types the duration of the exoerythrocytic phase is shorter than that of the blood infection, in striking contrast to the elongatum type, in which the exoerythrocytic stages are life-long. For the cynomolgi and falciparum types there is a passage from tissue to blood in one direction only; in these types, tissue stages can follow sporozoite inoculations only. These principal types of exoerythrocytic schizogony are exemplified in the following list (which does not claim to be inclusive):

Elongatum type occurs in \textit{Haemamoeba elongata} of birds. \textit{H. pitmani} of the African skink and \textit{P. berghei} of the Congo show certain affinities with this group but are not as yet definitely assigned to it.

Gallinaceum type is found in \textit{Haemamoeba} spp. \textit{gallinacea, relicta, cathemera, lupharae, and failua}; probably also in \textit{circumflexa, durae, nucleophila,} and \textit{hexameria} of birds.

\textsuperscript{1} In protozoological terminology the asexual process of development resulting in the production of schizonts is called schizogony; strictly speaking, all the asexual forms with multiple division of nuclei are schizonts, and the earlier undivided asexual parasites are trophozoites. In malaria terminology, however, the term "trophozoite" is generally applied to intracellular erythrocytic forms in their early stages of development.
Mexicanum type has so far been found only in *Haemamoeba mexicana*, a parasite of New World lizards, and probably in *H. pinotii* of toucans.

Cynomolgus type has been established for *Plasmodium* spp. *cynomologi*, *cynomolgus bastianellii*, *vivax*, *inui*, *malariae*, *gonderi*, *ovale*, and *knowlesi* of man or monkeys.

Falciparum type is found in *Plasmodium falciparum* (= *Laverania falcipara*) and probably in the crescent-producing *P. reichenowi* of the chimpanzee and gorilla.

Murinae type is found in *Polychromophillus murinus*, a parasite of bats. It is possible that *brodeni*, of the elephant shrew, also belongs to this group.

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**FIG. 1. TYPES OF EXGERYTHROCYTIC SCHIZOGONY**

**TYPE I-ELONGATUM**

**PRIMARY EE**
- Erythrocytic

**SECONDARY EE**
- Haemopoietic system

**TYPE II-GALLINACEUM**

**PRIMARY EE**
- R.E. system

**SECONDARY EE**
- R.E. system

**TYPE III-MEXICANUM**

**PRIMARY EE**
- Unknown

**SECONDARY EE**
- Fixed and wandering (including haemopoietic) cells
FIG. 1 (continued). TYPES OF EXOERYTHROCYTIC SCHIZOGONY

TYPE IV - CYMOEDGI

PRIMARY EE
LIVER PARENCHYMA
SPOROZITE

SECONDARY EE
LIVER PARENCHYMA

IMMUNE BARRIER POSITIVE
IMMUNE BARRIER NEGATIVE
ERYTHROCYTIC (PRIMARY) (ATTACK)
ERYTHROCYTIC (SECOND) (RELAPSE)
IMMUNE BARRIER VISIBLE
IMMUNE BARRIER NEGATIVE

TYPE V - FALCIPARUM

PRIMARY EE
LIVER PARENCHYMA
SPOROZITE

ERYTHROCYTIC (PRIMARLY ATTACK AND RECURRENCES)

TYPE VI - MURINUM

PRIMARY EE
ORGAN ENDOTHELIUM
SPOROZITE

SECONDARY EE
LIVER ENDOTHELIUM INVISIBLE UNTIL RELAPSE ENDOTHELIUM

ERYSOCHYTIC GAMOCTETES ONLY (PRIMARY ATTACK)
ERYSOCHYTIC GAMOCTETES ONLY (RELAPSE)

TYPE VII - KOCHI

PRIMARY EE
LIVER PARENCHYMA
SPOROZITE

SECONDARY EE
LIVER PARENCHYMA

ERYTHROCYTIC GAMOCTETES ONLY

13. Merozoites are young forms, the direct product of segmentation of either a tissue schizont or a blood schizont. They may be free or within a host cell. Trophozoites are asexual forms which are ring-shaped in the early stage but later appear as amoeboid or solid bodies with chromatin as yet undivided—that is, before the process of schizogony.\(^1\) Older trophozoites of *P. falciparum* are sometimes very motile in the red blood cell, and in films which have been dried quickly the cytoplasm may assume an irregular amoeboid shape, while the nucleus often appears divided. These forms, previously ascribed to a new species of human malaria parasite, are known as *teneue* forms of *P. falciparum*. Schizonts are asexual forms in which the nucleus shows evidence of division. There may be such forms with two, four, or more nuclei, but the merozoites, within the schizonts, have not yet been differentiated. Mature schizonts are fully developed schizonts in which merozoites have taken shape. These mature forms are also known as segmentation forms, segmenters, segmenting bodies, rosettes, sporonts or sporulation forms.\(^2\) Since the process here concerned is not that of spore formation, the terms "sporulation form" and "sporont" are incorrect, although other derivatives such as "sporogony" have been sanctioned by usage. The terms "segmenters" and "segmenting bodies", formerly much used, are now less employed, although the maturating of a generation and the 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.

14. Gametocytes, which are sexual forms of the parasite, develop within red blood cells\(^3\) and reach maturity in the mosquito's gut. The male gametocytes are called microgametocytes, and the females, macrogametocytes. Further changes, such as exflagellation and maturation, producing respectively the microgametes (flagella) and macrogametes, occur, as 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 host.

The gametocytes of *P. falciparum* and *P. reichenowi*, because of their characteristic appearance, are usually called crescents. It is not uncommon

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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.

\(^2\) Writers in Russian not uncommonly use this term, as well as the name "gamont", for sexual forms, and "agamont" for asexual forms, of the erythrocytic cycle of malaria parasites. Trophozoites are sometimes referred to as "young schizonts", while mature schizonts go by the name of "morula".

\(^3\) In a microscopic examination of malarial blood, the very young gametocytes which cannot be distinguished from trophozoites are counted as trophozoites.
to find the term “crescent” wrongly used as if all gametocytes were crescents. When the gametocytes of other species of the malaria parasite are meant, they should be distinguished as gametocytes of the relevant species.

15. When trophozoites are growing and maturing it can usually be seen that relatively large numbers are 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 groups ("broods") 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 time period which each species of parasite requires 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 period of the blood phase of the parasite.

Structure of the parasite and the changes produced by it in the red blood cell

16. Laboratory confirmation is the only incontrovertible proof of malaria infection and is obtained through demonstration of malaria parasites in blood films by microscopic examination. Repeated examinations may be necessary; the thick film stained with one of the Romanovsky stains is the method most likely to reveal the parasite, although its morphology and its relation to the red blood cell are shown best in the thin film.

Terms relating to the morphology of the parasites are cytoplasm, nucleus ("chromatin") 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 this would appear to be the best term. Malaria pigment, often referred to as haemozoin, is now known to be a compound of haematin with protein; the term "melanin", formerly used, is not recommended.

17. Among the abnormal appearances of the host's red cells brought about by the parasites developing inside them 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 or stippling) brought out commonly by the various forms of the Romanovsky stain in vivax-, and the coarse, more irregular markings (Maurer's spots or clefts) seen in falciparum-infected cells.1 Granulations similar to those in vivax are seen in ovale malaria.

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 also by Stephens & Christophers, before Maurer.
(James's stippling); another form brought out only by special staining in malarial infections is called Ziemann's stippling. Other changes described are the "brassy corpuscles" of early writers seen in fresh preparations with falciparum malaria, and an oval shape of the cell associated with a wavy edge at one or both ends (crenation or fimbriation) in ovale infections.

**Forms of the parasite in the invertebrate host**

18. On entering the midgut of the female anopheles, the male and the female gametocytes undergo exflagellation and maturation respectively; in the male the microgametes (sometimes called flagella) are set free; the female parasite escapes from the red blood cell when the macrogamocyte becomes the macrogamete. On fertilization the macrogamete undergoes further changes, becoming the ookinete (sometimes called "travelling vermicule"). The ookinete in turn, after passing through the gut wall, becomes the oocyst. The first division of the nucleus is meiotic, subsequent divisions are mitotic. Within the oocyst are developed the sporozoites which invade the salivary glands.

The term "zygote" (strictly, the entire product of sexual union) was formerly used 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. The whole process of development occurring in the mosquito following the sexual union of gametes is called sporogony. It may also be referred to as the extrinsic phase.

**Nature and course of malarial infection**

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

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

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

3. those connected with treatment, prophylaxis, or control.

Malarial infection may be due to a transmission occurring naturally through exposure to infective anopheles or it may be artificially brought about for the purpose of malariotherapy or experimentation. In the latter case (induced malaria) the infection may be transmitted (1) through the bite of an infective mosquito or through the injection of its salivary glands containing sporozoites (sporozoite-induced malaria), or (2) through
the injection of infected blood (blood-induced malaria, trophozoite-induced malaria). Malarial infection may also be brought about unintentionally, generally by blood transfusion from an infected donor or by use of a contaminated syringe or needle (accidentally induced malaria). The infection may also be transmitted from the mother to the foetus transplacentally or to the newborn infant during labour (congenital malaria).

When the infection is due to two or more species of malaria parasites the term "mixed infection" is used.

20. Clinically, following the infection, there is an incubation period, which comes to an end with the onset of the primary attack. This first attack is frequently followed at intervals by others due to the same original infection. A subsequent attack has been variously designated by different authors in relation to the time of its occurrence as a recrudescence (short-term) or a recurrence (long-term), or generally as a relapse. These terms, though not entirely satisfactory, are defined in the Glossary. There is often no reliable means for identifying the type of subsequent attack.

By attack, whether primary or subsequent, is meant the whole period of acute (overt) illness, which may consist of a number of separate paroxysms or short manifestations of malaria or of a single paroxysm only. It may also, however, consist of a period of irregular high fever extending over a number of days when the separate paroxysms are indistinguishable (as in falciparum malaria or at the onset of the first vivax infection), or of such a period followed by a succession of paroxysms.

When the paroxysms are distinct, with an interval of normal temperature, and follow regularly, the fever may be described as of intermittent type; when the high temperature fluctuates for some days without becoming normal, it is said to be of remittent type. It is undesirable, however, to use the terms "intermittent" and "remittent" in such a way as to imply (as in the older writings) that these terms characterize certain forms or types of malaria.

21. The typical course of a paroxysm of malaria comprises the well-known three stages (cold stage with rigor, hot stage and sweating stage); there may also be a premonitory stage (headache, nausea, malaise), which precedes the rigor.

The occurrence of a paroxysm normally depends on the schizogony of a generation of erythrocytic parasites. It is believed also that there is a

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1 James (1931) classified subsequent attacks in vivax infections as follows:
   "Recrudescence: a return of fever and parasites at any time within 8 weeks after recovery from the primary attack.
   "Relapse: a return of fever and parasites later than 8 weeks but earlier than 24 weeks after recovery from the primary attack.
   "Recurrent: a return of fever and parasites more than 24 weeks after recovery from the primary attack. This means as a rule later than 26 weeks after the date of primary infection."
definite quantum of parasites the presence of which in the body will cause pyrexia (pyrogenic level). This level varies, however, not only from subject to subject but even in the same subject, according to the degree of immunity.

The number of generations of the malaria parasites present at a given time in the blood, and the schizogonic period of the parasite, determine the clinical periodicity. Such periodicity may take the form of paroxysms on alternate days (tertian periodicity) or on every third day (quartan periodicity); of paroxysms occurring daily (quotidian periodicity), due in man to interpolated generations; or of paroxysms occurring on two successive days with a one-day interval (double-quartan periodicity).

Associated with infection there are also general pathological effects, some of them due to the blocking of blood capillaries in various organs by localized masses of parasites (P. falciparum). The clinical characteristics of such pernicious manifestations (e.g., cerebral malaria) are distinct from those of the common malarial attack. They are variously named according to the organs affected or the clinical symptoms.¹

22. Following on infection there may be various sequelae such as anaemia or cerebral symptoms. The term "malarial cachexia" was previously used to indicate a condition of intense anaemia, splenomegaly, wasting, oedema and other consequences of prolonged infection. Much of the "malarial cachexia" described by older writers, especially in India, was, however, really due to deficiency diseases, ancylostomiasis or kala-azar. The term is now less commonly used. Various minor manifestations in human subjects, assumed to be the result of previous malarial infection, were sometimes described (particularly when they exhibited periodicity or were modified by quinine administration) as latent or larval malaria, terms now very rarely 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 some authors).

"Chronic malaria" is a vague 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.

23. Malarial infection² is followed by an incubation period during which there are no clinical symptoms (premonitory signs or febrile response); the expression "prepatent period" refers to the time which elapses between

¹ A description of the effects of malaria infection on various tissues and organs and a discussion of the pathogenesis of the lesions will be found in Mungraithe (1948).
² The term "infection" is used for both the introduction of infective material—i.e., inoculation (by natural or artificial means)—and for the resulting condition. The two usages are, however, rarely confusing.
infection with the parasites and their appearance in the peripheral blood. There is also a subpatent period during which parasites may be present in the blood in such small numbers that they cannot be detected by ordinary microscopic examination of one or even several blood films (Fig. 2).

These stages are followed by clinical symptoms usually associated with parasite patency. The primary attack is composed of a number of paroxysms and is usually succeeded (except when parasites have been eliminated by adequate treatment) by a more or less prolonged period in which the evidences of infection depend on the interacting processes of multiplication of the parasites and immunity reactions of the host. Infection in this state may be unassociated with parasitological or clinical manifestations ("latent") or may be evidenced by either or both of these conditions ("active"). Each such 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 of the blood ("parasitic relapse").

24. There are cases and conditions in which malaria parasites are present in the peripheral blood without pyrexia or any other relevant symptoms except for a possible enlargement of the spleen. A person with asymptomatic parasitaemia is called a symptomless parasite carrier.

Two main types of asymptomatic parasitaemia are classified according to their relationship to the course of malaria infection. Primary asymptomatic parasitaemia is that in which malaria parasites are present in the blood at the end of the incubation period before the clinical symptoms of the primary attack; in some cases primary asymptomatic parasitaemia may not be followed by the appearance of clinical symptoms, but the evidence of such occurrences must be accepted with caution. Asymptomatic parasitaemia occurring at any time after a primary clinical attack is known as secondary; if related to recrudescences or relapses it is termed intercurrent, except if it follows the last clinical relapse, when it is called terminal (i.e., bringing the infection to an end).

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

25. A number of terms are used in connexion with the study of infection and immunity. Those forms of parasite which are distinguishable by morphological characters constitute species or subspecies. Parasites of the same species or subspecies may, however, show differences in immunological
FIG. 2. PHASES OF A MALARIA INFECTION SHOWING RELAPSES OF THE RECRUDESCENT AND RECURRENT TYPES

1 — Incubation period
1a — Pre-patent period
2 — Primary attack composed of paroxysms
3 — Latent period (clinical latency)
4 — Recrudescence (short-term relapse)
5 — Latent period
5a — Parasitic latency
6 — Clinical recurrence (long-term relapse) followed by parasitic recurrence
6a — Parasitic relapse
and other characters. The term "strain" (see para. 123) is used in parasitology for forms of the parasite which show well-defined immunological characters different from those shown by other forms of the same species; several species include an unknown number of immunologically distinct strains. Those which behave in a similar manner immunologically are said to be homologous strains; those which behave in a dissimilar manner immunologically are called heterologous strains.

26. When parasites have established themselves in a host, the host is said to be infected; a reinfection is a new infection occurring after all the original parasites have been eliminated through a natural process of recovery or through radical treatment. A superadded infection brought about in the host while the original infection is still present constitutes a superinfection. So long as the original infection is present, inoculation of a host with the same strain usually leads to only a very slight and transient increase, if any, in the number of parasites. But superinfection with a heterologous strain may bring about a primary attack in an already infected host, i.e., a new infection.

27. When repeated microscopic examination of the blood of a host fails to reveal infection, it may become manifest if the blood is inoculated into another susceptible host. If the original host is found to be refractory to an attempted infection, this also may be an indication that he is already infected. Latent infections have sometimes become manifest after removal of the spleen. An exceptional method of diagnosis of malaria is that of feeding known anopheline vectors on the suspected host with subsequent examination of the mosquitoes for the presence of oocysts or sporozoites ("xenodiagnosis of malaria").

28. Malarial immunity in the vertebrate host is the state of resistance to the disease brought about by all those processes which prevent infection, reinfection, or superinfection; 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. All the processes involved in malarial immunity appear to be related to the activity and quantum of the plasmodia in the erythrocytic, but not in the exoerythrocytic, stages.

Generally speaking, immunity depends on the physiological condition of the host and on the activity of its defence mechanism, which comprises both humoral and cellular factors. These factors contribute jointly, though in various degrees, to the development of immunity. The humoral factors are represented by antibodies which appear in the blood, generally, but not invariably, in response to the introduction of foreign proteins
(antigens) into the body of the host. The cellular factors are represented by the free or fixed cells of the lymphoid macrophage system.

29. There are two types of immunity, natural and acquired. Natural immunity to malaria is an inherent property of the host, a refractory state or an immediate inhibitory response to the introduction of the parasite, not dependent on any previous infection with it. An example of such response (also known as innate immunity, innate resistance, genetic immunity and species immunity) is the natural immunity of man to avian plasmodia (in relation to the parasite, this is described as host restriction).

Acquired immunity may be either active or passive. Active immunity is an enhancement of the defence mechanism of the host as a result of encounter with the infective agent or its antigenic components. Active immunity to malaria is consequent upon a specific response of the host to contact with the parasites or their products; it might also result from inoculation with killed or attenuated plasmodia, but this has not yet been demonstrated. Passive acquired immunity is conferred by the prenatal or postnatal transfer of protective substances from mother to child or by the injection of specific antibodies. There is evidence of such congenital (or neonatal) immunity in the early postnatal life of some offspring of immune mothers and in some human populations of highly endemic malarious areas.

The protection acquired by a host against subsequent reinfection with a homologous strain, and maintained for variable periods of time after destruction of malaria parasites and subsequent recovery, is known as residual immunity. In infections with malaria parasites the protective response of the host is not, however, necessarily related to the presence of residual immunity but may result from premunition.1 Premunition is a state of resistance in a previously infected host due to the continued presence in the organism of a small number of surviving parasites; such a state affords protection against a new infection with homologous strains and disappears with the elimination of the parasite.

30. The term "tolerance" 2 describes an effect of immunity characterized by a lessening of the response of the host to a given quantum of infection. "Tolerance" may also sometimes be employed to describe resistance to infection by a small number of parasites which can be overcome by infection

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1 This term was coined by Sergeant, Parrot & Donatien (1924) but the state has been known under various other names, such as tolerance immunity, infection immunity, relative immunity, and concomitant immunity (Sargent, 1961).

2 "Tolerance" is here used in the orthodox, time-honoured sense and expresses the effect of the immune response of the host to the presence of the parasite. It should be pointed out that with the recent broadening of concepts in immunology the term "tolerance" is now often used in a different sense. Thus "immunological tolerance" describes the failure of an individual to develop an immune response to an antigen previously encountered in embryonic or perinatal life. A discussion of modern immunological ideas will be found in Hurst (1962).
with a larger number of parasites. Thus tolerance and immunity are not wholly synonymous. High degrees of tolerance appear to be related to the active acquired immunity found in holoendemic areas.

31. A person infected with malaria is said to be "infectious" 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 itself, however, should be termed "infective" if, by reason of asexual forms of the parasite contained in it, it can convey malaria to a susceptible human host when given by parenteral injection.
II. MEASUREMENT OF MALARIA IN THE HUMAN COMMUNITY

Statistical and epidemiological aspects

32. In the assessment of the amount or degree of malaria in an area or community, a number of epidemiological and statistical concepts are employed.¹

The word “endemicity” is a useful term referring to a general assessment of the measurable incidence and the degree of natural transmission of malaria. Methods which aim at recording and measuring the endemic and epidemic prevalence of malaria in communities form the subject of malariology.

The term “malaria survey”, as used traditionally, meant an evaluation of the endemic or epidemic status of malaria in a community or an area; such a survey estimated not only the amount and the main features of malaria, but also all the underlying factors pertaining to the natural history of the disease in the community. The newer term “malariometric survey” has a more precise meaning and refers to the measurement of the amount of malaria by the use of spleen and parasite rates determined on comparatively small random samples of the population, often restricted to young age groups. These surveys assess the distribution and degree of malaria.

33. Two types of measurement are commonly used for the assessment of the amount of malaria: incidence and prevalence. “Incidence” refers to the number of cases of disease or infection occurring per unit of population during a defined time interval. “Prevalence” refers to the number of cases of disease or infection existing in a population at any given time. It is important to distinguish these two measurements, as they require different methods for their determination.

The term “intensity” is often loosely applied with reference to the degree of endemicity, to the severity of infection—i.e., the parasite density—or to the likelihood that an individual in a malarious area will contract the disease. This loose term should be replaced by more precise terms indicating the particular measurement referred to.

¹ Discussion of general problems of statistics applied to public health was deliberately omitted in this chapter. The interested reader will find them in standard textbooks. Problems of collection and interpretation of data are lucidly presented by Swaenop (1959 and 1960).
The terms "index" and "rate" express the relationship between various frequencies or counts. 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. The essential feature of a rate is that it is a relative number or a statement of numerical proportion prevailing between two things. The word "index" should be applied to a measurement of one type of value used to assess or indicate another. Thus the proportion of palpably enlarged spleens in a group is the spleen rate of the group, but it supplies an index of the endemicity of malaria in the population.1

The morbidity rate (or morbidity) from malaria would be (theoretically) the proportion of the number of cases of malaria in a given unit of time to the population in which they occur. Except in conditions where case detection is carried out to perfection, such a rate is rarely measurable, and morbidity rates as normally reported are based on recorded admissions or attendances at dispensaries; these in turn depend on the circumstances controlling admission or attendance. Frequently, also, the exact size of the population to which such figures relate is unknown. The malaria morbidity rate is closely related to (or sometimes identical with) the malaria incidence. It is usually expressed in relation to a population of 1000 (instead of 100,000, as in other diseases) and may be qualified, if desired, for age, sex or other attributes.

34. The true mortality rate (or death rate) from malaria is in practice as indeterminable as the true morbidity rate, but for different reasons. The recording of deaths may give little information of real value because some of the deaths recorded as due to malaria are in reality caused by other conditions; contrariwise, deaths directly or indirectly due to malaria are often not recorded as such. This is especially likely to happen because in areas of high endemicity, mortality rates from malaria refer mainly to infants or children, among whom, even with medical supervision, diagnosis may be 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.

Naturally, during epidemic outbreaks deaths caused by malaria are more evenly distributed among all age groups, and the value of the specific mortality rate is correspondingly greater.

1 The Drafting Committee considered the question, raised by Ronald Ross some fifty years ago and mentioned in the Report on Terminology of Malaria (League of Nations, 1940), whether the spleen rate, parasite rate and other rates should be renamed "spleen index", "parasite index," and so on because they indicate proportions ascertained in a sample and not in the whole community (see pages 161-163 of the Report). The Drafting Committee confirmed the conclusions of that Report and of the Terminology of Malaria (World Health Organization, 1953), that "rate" is the more suitable term for these, especially as (in English) it has the claim of long usage and custom. While the term "rate", in the view of the Drafting Committee, should be retained in English for spleen rate, parasite rate, sporozoite rate, etc., it is realized that in many other European languages (e.g., French, Spanish, Italian, German and Russian) the Latin or national linguistic equivalent of the term "index" is used.
For the above reasons, the figure for total deaths (i.e., deaths from all causes) in an area may, in some circumstances, be more valuable as material for statistical study than the statistics of malaria mortality. This applies particularly where malaria occurs in epidemic form and where there is good general registration of deaths, irrespective of correct diagnosis of the cause of death. In such conditions, the effects of the disease may cause considerable variation in the recorded number of total deaths, such effects being evidenced by characteristic peaks in the graph of total (weekly) deaths, the so-called “epidemic rises” of Indian observers. The measure of such a rise is the “epidemic figure”, which is the number of deaths in a selected epidemic month divided by the normal number of monthly deaths for the area. By plotting such epidemic figures for numerous small registration districts it is possible to map out the severity and distribution of regional epidemics (for description of the method, see Christophers, Sinton & Covell, 1945).

Origin of infection

35. A number of epidemiological terms are applied to the distribution, prevalence and significance of malaria in human communities.

Malaria is called “autochthonous” when it is contracted locally. Autochthonous malaria that is natural to an area or country is termed “indigenous”; autochthonous malaria that is due to the local transmission of an infection from cases brought into the area from outside its geographic or epidemiological limits is called “introduced” malaria.

The term “imported malaria” refers to cases of disease in which the infection was acquired outside the given area and cannot be traced to local transmission. Imported malaria is subclassified, for the purposes of malaria eradication programmes, according to whether cases are imported from abroad or from within the country, and, in the latter case, whether they come from outside the project area or from parts of the project area which are in a specified phase of the eradication programme, e.g., the attack phase or the consolidation phase.

Malaria resulting from infection artificially produced for the purpose of malarial therapy or caused accidentally by injection is known as “induced malaria” (see also para. 19).

Malaria may be described as sporadic when autochthonous cases are too few and scattered to cause any appreciable effect on the community. Sporadic cases are often due to relapses of a previous infection; for the purpose of epidemiological classification, the term “relapsing” is then preferred.

When malaria of any distribution or degree is the direct outcome of human activities, especially those giving rise to an increase in breeding
places—e.g., borrow-pits, railway embankments, or irrigation ditches—it is often referred to as “man-made”.

**Epidemicity and Endemicity**

36. “Epidemic malaria” is a term indicating, at times somewhat loosely, a periodic or occasional sharp increase in the morbidity or mortality of the human community due to malaria. It has been applied to a number of more or less different conditions:

(1) an outbreak of malaria among a population in which malaria was previously unknown (“epidemic outbreak”);

(2) an occasional exacerbation of malaria in an area of usually low endemicity (“epidemic exacerbation”);

(3) seasonal rises of malaria incidence in areas of usually low endemicity (“minor seasonal epidemics” or, when they reach unusual heights—at intervals of three, five, or more years—“major seasonal epidemics”; the latter comparable to the epidemic exacerbations described above);

(4) seasonal rises of malaria incidence in areas of high endemicity.

Epidemics of the sort described in (1) and (2) are characterized by the fact that they affect all age groups to almost the same extent. Spleen rate, parasite rate, and parasite density are high in children and adults alike, except that the older adults, in epidemics of type (2), may show somewhat lower rates. The minor seasonal epidemics described in (3) show more moderate spleen and parasite rates and parasite count and a more or less marked tendency to spare the adults. The seasonal rises mentioned under (4) affect only the lowest age groups, leaving the higher ones unaffected or almost so, at any rate in areas of the highest endemicity (“holoendemic regions”).

The use of the term “epidemic” should preferably be restricted to the conditions described under (1) and (2); those mentioned under (3) and (4) should be termed “seasonal rises” of malaria incidence. Defined in this sense, 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 the immigration of unprotected workers into malarious areas.

Malaria is described as endemic when there is a measurable incidence both of cases and of natural transmission over a succession of years. Various terms have been used to designate degrees of endemicity; none of them are fully satisfactory in all circumstances. The following classification, based on the spleen rate (the percentage having enlarged spleens) in different age groups, is a slightly modified form of that proposed by the Malaria Con-
ference in Equatorial Africa held in Kampala in 1950 (World Health Organization, 1951):

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.

The proportion of enlarged spleens in the various age groups cannot always, however, be taken as a reliable index of the amount of malaria; in some populations exposed to an intense and nearly perennial transmission, the adults seem to acquire a considerable degree of immunity to malaria and yet show a high frequency of palpable spleens, for reasons not fully understood. For such areas a classification of endemicity of malaria has been proposed (Metselaar & Van Thiel, 1959) based on the parasite rate and using the same classes:

Hypoendemic: parasite rate in children of 2-9 years as a rule less than 10% (may be higher during part of the year).
Mesoendemic: parasite rate in children of 2-9 years as a rule 11%-50% (may be higher during part of the year).
Hyperendemic: parasite rate in children of 2-9 years constantly over 50%.
Holoendemic: parasite rate in infants ³ constantly over 75%, spleen rate in adults high (New Guinea type) or low (African type), parasite density declining rapidly between second and fifth year of life and then more slowly.

In addition to being based on the results of blood examination only, the above classification differs from that formulated by the Kampala Conference (World Health Organization, 1951) in that the criterion for the holoendemic class is determined in the infant age group rather than the 2-9 age group.³ This in itself would be acceptable, but the proposed classification of holoendemic malaria might be subject to errors depending on the actual age composition of the infant group.

Many more data from the field are necessary before a general classification of endemicity other than that proposed by the Kampala Conference can be recommended. Difficulties will in any case remain when attempts are made to fit biological events into a rigid system.

A more general classification, based on appraisal of the transmission factors and the subsequent collective response of the human population, distinguishes two extremes of a dynamic series of happenings and refers to "unstable" and "stable" malaria. This classification integrates the

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³ In the original paper this is described as the "one-year age group".
³ The parasite rate for children of 2-10 years was noted previously by Stephens & Christophers (1902) for purposes of comparing and mapping endemic malaria. It was then known by the term "endemic index", defined by Ross (1910) as the proportion of children aged 2-10 years showing evidence of malaria by either presence of parasites or spleen enlargement or both.
various factors which have a bearing on the epidemiology of malaria and is of undoubted value even though it does not provide a simple method of classifying the endemicity of malaria from the results of a few surveys.

In stable malaria the amount of transmission is generally high and not subject to any marked fluctuations over the years. The resulting collective immunity of the population is high, and epidemics are unlikely. On the other hand, in unstable malaria the amount of transmission is of varying degree and subject to marked seasonal or other fluctuations, so that the resulting collective immunity of the population is variable and often low.

Transmission of infection

37. The source of human malaria infection is always a human subject, whether a sick person or a symptomless parasite carrier. The period elapsing from the time when an individual is infected to the moment when he becomes infectious to the malaria vector, known as the infection interval, is not the same as either the incubation period or the incubation interval.

The transmission of malaria infection from an infectious person to a susceptible recipient human host is related to a number of factors whose mutual relationship is of great complexity. The basis for the study of quantitative aspects of malaria transmission was laid down by Ross (1910) and has been further developed by Macdonald (1957). Among the most important concepts is the reproduction rate, which is the number of infections distributed in the population through the agency of the vector by the average infected individual in that community. The magnitude of the reproduction rate indicates the amount of potential transmission. The actual amount of transmission can be assessed from the inoculation rate, which is the proportion of the population receiving the infective inoculum in a given unit of time. This inoculation rate can be estimated from the entomological data or indirectly through analysis of the parasite rate in infants (Macdonald, 1950).

The natural transmission of malaria infection may be classified either from the epidemiological point of view as perennial or seasonal, or from the operational angle of malaria eradication, when it is more important to determine whether transmission is residual or renewed. The cessation of transmission of malaria as a result of antimalarial measures is referred to as “interruption of transmission”, one of the first goals on the road to malaria eradication.

Age-grouping

38. In specifying age groups there is some difficulty in avoiding ambiguity, especially in concise presentations, such as tables; the age group 0-2 years
of some authors may be identical with the age group 0-1 year of others employing a different method of statement. Age is most commonly taken as that on the last birthday. In this method of stating age, a two-year-old child may be of any age from two to just short of three years. But to describe a child as two years or over but under three years, especially when defining age groups in order to avoid ambiguity, is both troublesome and clumsy. One way to obviate this difficulty without sacrificing accuracy would be to adopt a convention by which any given age figure would be understood to include those from that age to just under the next year (or month) 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>&quot; Toddlers &quot;, 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>

According to this scheme the age group 0-11 months will include all children under 12 months of age. A child of 12 months but under 24 months will be classified in the next age group. It should be noted that for the purpose of tabulating national mortality statistics by cause of death a slightly different age-grouping has been recommended (World Health Organization, 1957); the main difference is its use of a single group for small children of 1-4 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. Where this method is used there are bound to be inaccuracies, but the figures obtained are usually adequate for the purpose of tropical field work.

Whatever method is used, it is always desirable to state clearly the convention adopted and the way in which the ages have been determined.

In parts of the world where it is difficult to secure correct information on age, it is necessary for the investigator to estimate the age by physiological milestones or other means. The following signs are useful for the estimation of ages below one year when such classification is necessary, as, for instance, for the analysis of parasite rates in infants.

<table>
<thead>
<tr>
<th>Age, months</th>
<th>Eruption of deciduous teeth</th>
<th>Neuromuscular development</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>—</td>
<td>Smiling in response to an adult, uttering spontaneous sounds</td>
</tr>
<tr>
<td>4</td>
<td>—</td>
<td>Head control when brought to sitting position</td>
</tr>
</tbody>
</table>
MALARIA IN THE HUMAN COMMUNITY

<table>
<thead>
<tr>
<th>Age, months</th>
<th>Eruption of deciduous teeth</th>
<th>Neuromuscular development</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-7</td>
<td>Central lower incisors</td>
<td>Sitting unsupported for a few moments, beginning to crawl</td>
</tr>
<tr>
<td>8-10</td>
<td>Upper incisors</td>
<td>Picking up small objects, bringing the thumb and index finger together</td>
</tr>
<tr>
<td>10-14</td>
<td>Lower lateral incisors</td>
<td>Pulling self to standing position, standing without support for a few moments, taking a few steps</td>
</tr>
</tbody>
</table>

These milestones vary widely, however, not only in different racial and socio-economic groups but between individuals. Thus some distortions of the age structure of the sample of the population may result, and any epidemiological conclusions must be appraised with caution. The estimation of age from the development of deciduous teeth is less easy than it would appear, as there is considerable variation in the time of eruption. There is an interval of approximately one month between the first appearance of a deciduous incisor and the eruption of its crown; the molars usually take twice as long.

In older children the estimation of age from the teeth is even more difficult. For the deciduous teeth, a rough approximation is as follows:

<table>
<thead>
<tr>
<th>Age, months</th>
<th>Eruption of deciduous teeth</th>
</tr>
</thead>
<tbody>
<tr>
<td>12±3</td>
<td>First molars</td>
</tr>
<tr>
<td>18±3</td>
<td>Canines</td>
</tr>
<tr>
<td>27±6</td>
<td>Second molars</td>
</tr>
</tbody>
</table>

The important teeth are the second and third molars on each side of the upper and lower jaws. (When identifying these teeth the examiner must not be misled by the presence of occasional supernumerary teeth, which are always smaller than normal and peg-shaped.) Of the permanent teeth, the first molar erupts fairly consistently in both sexes between the fifth and seventh year; the second molars erupt at about the twelfth year. If all these teeth are present but no third molars have erupted, the child is certainly over 12 years but less than 15 years. The third molars erupt in Africans relatively early but generally not before 15 years of age. If three or four third molars are visible in the mouth the subject is certainly over 18 years of age.

An attempt was made in West Africa to construct age-height tables from which the age of the pre-school child or school child could be estimated. It is obvious that such an estimate has a margin of error which can amount to 2-3 years in any given individual according to his physiological development, nutritional level and other variables. Nevertheless in a large sample this method may be of value, and its use after adaptation to various areas and different socio-economic conditions can be recommended until such time as the reporting of vital statistics is introduced and widely accepted in developing countries.
39. 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 (1908) was the first to make systematic use of the degree of enlargement of the spleen to measure malaria in a malarious community. Numerous observers have subsequently used these methods.

The object of palpation of the spleen is to determine (1) the percentage of individuals with demonstrable enlargement of the organ, and (2) the approximate degree of enlargement.

The proportion (expressed as a percentage) of the population with palpably enlarged spleen is generally known as the spleen rate. This rate must not be regarded as the over-all percentage showing splenomegaly in the community: it has been found that the rate in children often differs greatly from that in adults and, for various reasons, is more representative as a preliminary measure of malaria. The spleen rate as ordinarily understood and used by malariologists has therefore come to mean the percentage of children with enlarged spleens in a community on a given date.

In relation to both parasite-rate determinations and observations on splenomegaly, the social status of the children examined is important: as a rule, the lower the status, the higher the parasite rate and also the incidence of splenomegaly. For this and other reasons, school children are apt to show lower rates than children collected in villages or in the streets of a town. On the other hand, the much larger samples obtainable in schools, the feasibility of examining the same group at different times, and the fuller information available about each child are distinct advantages. Because much depends on the circumstances in different countries or areas, it is impossible to lay down a strict rule; but it is desirable that when malariometric rates are based on the examination of school children only, this fact should be stated.

40. The age group usually selected is that which includes children in the third to tenth years of life, i.e., age group 2-9 years (though some workers prefer to limit this sample to the 5-9 age group, which can more easily be collected for the examination). 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 mothers' 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 malaria season, may not yet have had time to develop splenomegaly. In the age group 10-14 years, the enlargement of the spleen is often considerably reduced in contrast to the age
group 2-9 years, in which enlargement is generally very constant. In adults, the size of the spleen may even be in inverse relation to that in children; a very high degree of malaria infection with a high spleen rate in children may sometimes be associated with a greatly lowered adult spleen rate, though in other circumstances both the child spleen rate and the adult spleen rate may be high.

41. In general there are among malarologists two procedures for palpation of the spleen: that in which the subject is examined standing and that in which the subject is examined lying down. The latter position is preferred especially when the number of spleens with moderate enlargement is high. Every effort should be made to secure relaxation of the abdominal wall and to avoid the intervention of clothing between the palpating hand and the abdomen. It is emphasized that spleen palpation requires special training, because it is easy to mistake something else for a spleen with moderate enlargement. In the absence of kala-azar, of some forms of bilharziasis, of acute exanthematosus disease, or of very recent vaccination against smallpox, a spleen rate above 10% is highly suggestive of malaria. Comparison of spleen rates recorded in different countries by different observers is greatly facilitated by a record of the size of the spleen; this is 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.

Spleen rate and the measurement of the enlarged spleen

42. As noted, the spleen rate is usually defined as the percentage of children aged 2-9 years showing palpable enlargement of the spleen. A similar proportion in adults is specified as the adult spleen rate; the proportion may be determined for any desired age group. The spleen rate is a valuable measure of endemic malaria. It is less liable to seasonal variations than the parasite rate. A further advantage is that its determination involves little expenditure of time.

The methods formerly employed by different malarologists to measure and record the size of the spleen ("spleen census") varied considerably, but a degree of standardization is now being achieved. Assessment of the degree of splenic enlargement 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, such as the average enlarged spleen, may be arrived at.  

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3 Because of this constancy it is less desirable to split up this age group into ages 2-4 years and 5-9 years than it is when dealing with parasite density.

4 The splenometric index proposed by Parret & Catanz (1958) is a single-figure index designed to include degree of splenomegaly as well as the spleen rate (spleen rate/average enlarged spleen). 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.
Many ways of classifying splenic enlargement have been proposed, but the following classification described by Hackett (1944) is becoming a generally accepted standard:

<table>
<thead>
<tr>
<th>Class of spleen</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>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 class 4.</td>
</tr>
</tbody>
</table>

This classification is illustrated in Fig. 3, where the approximate limits of the different classes of enlarged spleen are projected on the abdominal surface.

**FIG. 3. CLASSIFICATION OF SPLEEN SIZES ON PALPATION ACCORDING TO HACKETT**

![Diagram showing classification of spleen sizes](image-url)
43. The average enlarged spleen is a weighted average calculated by multiplying the number of individuals in each spleen class (except class 0) by the class number, adding these products, and dividing the total by the number of those whose spleens are palpable. Since the average enlarged spleen is determined from an arbitrary classification of the size of the spleen, it is essential for comparison that a standard classification of splenic enlargement such as the above be followed exactly. The data from which the average enlarged spleen is calculated should be recorded in some such form as that shown in Fig. 4. Data giving the number of enlarged spleens in each class can also be recorded as the frequency distribution of the classes.

**FIG. 4. RECORD FORM FOR SPLEEN MEASUREMENT**

<table>
<thead>
<tr>
<th>Class of spleen</th>
<th>Age group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-23 months*</td>
</tr>
<tr>
<td></td>
<td>2-4 years</td>
</tr>
<tr>
<td></td>
<td>5-9 years</td>
</tr>
<tr>
<td></td>
<td>10-14 years</td>
</tr>
<tr>
<td></td>
<td>Adults</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>

* Rarely used.

Some authors prefer to assess the size of the spleen by direct measurement of the distance from the apex of the spleen to the umbilicus and to the mid-line of the body. This method was found practicable in field work in India some years ago but is now seldom used.

**Spleen measurements as indices of endemicity**

44. In practice the spleen rate has been more widely used in measuring and mapping malaria than any other method. Where malaria is stable (the most usual condition in tropical communities) the spleen rate gives a good measure of its endemicity. Even in epidemic conditions it affords an indication of the prevalence of the previous infection. While no single quantitative expression can be expected to include all the factors in malaria prevalence, the spleen rate appears to be the best broad general measure of the "malariousness" of a community or area.

Stable malaria tends to produce in those infected a more or less fixed degree of splenomegaly relative to the age group. The average-enlarged-spleen values may indicate the difference in the incidence of malaria or in its
seasonal prevalence between two communities which have the same spleen rate. A reduction in the value of the average enlarged spleen may precede a reduction of the spleen rate and is of value in judging the changing malarial condition of the community.

Examination of the blood

45. One measure of the prevalence of malaria would be the proportion of persons in a given community who have the parasites of malaria in their blood at a given time. The difficulty in regard to such a measure is that single blood examinations do not reveal all the infected persons in the community. The number of blood films found positive is never exactly equal to, and may be widely different from, the true number of infections over a definite period.

Before discussing the terminology and the definition of such terms as parasite rate, parasite count and parasite density, it is therefore desirable to refer briefly to the relation between results obtained by examination of the blood and the actual presence of malaria parasites in the blood. If we examine blood films from an infected population (preferably a child population), we shall find that the number of cases detected will vary with the number of microscopic fields studied. In any such population, many of the infections are likely to be of a relatively high order, say 1000 parasites or more per cubic millimetre of blood. Most such infections will be detected by examination of a few fields of a thick film. However, a number of infections of a smaller order, say 100 parasites or less per cubic millimetre, examined in such a way will remain undetected. But an increased number of such infections will be brought to light as more and more time is given to the examination, that is, as more and more blood is examined.

It would be impracticable to examine each slide for a very long time in order to find every single infection in the sample of blood slides investigated. An arbitrary number of microscopic fields (100 or 200) or a time limit based on previous experience have been generally adopted for practical purposes. It is commonly agreed that the standard time for examination of a thick blood film should be five minutes, during which time the average microscopist can examine 100 microscopic fields, which represent only 0.1-0.2 mm² of blood. Naturally, the examination of a corresponding volume of blood spread out as a thin film will take 10-20 times as long.

46. Two important points arise here: (1) the parasite rate, without some indication of the degree of parasitaemia of each positive film (parasite count), gives a very imperfect idea of the real degree of parasitism in the community, which may consist entirely or mainly of very light infections or of quite heavy infections; (2) the parasite rate itself is largely dependent
on the number of heavy infections present, since the heavier the infection the greater is the likelihood that it will be detected in a blood examination of any given duration. The validity of the parasite rate ascertained is therefore dependent on the time devoted to the examination of each slide. With only a small increase of labour it is possible to obtain the information needed for both the parasite rate and the collective degree of parasitaemia (parasite density) from a single set of slides. This is done by using one of the simple routine counting methods described below in the section on parasite density.

For purposes of case detection alone the degree of blood infection is irrelevant, since each positive case will have to be dealt with irrespective of the degree of parasitaemia. But in some conditions of very detailed epidemiological survey it is desirable, when specifying infection in a community, to give not only the parasite rate, but also an indication of the parasite density. These two values represent the two separate measurements of the prevalence of infection and of its degree. An even more complete picture of the character of infection in a community is obtained from a study of the frequency distribution of infections with different species of parasite.

**Parasite rate**

47. The parasite rate should always be defined with reference to the age group examined. Thus the percentage of adults showing parasites of any species of *Plasmodium* is the adult parasite rate; that of children aged 0-11 months is the infant parasite rate.

The age group 2-9 years has often been used for measurement of the amount of malaria in a community and for the classification of endemicity. 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, and the latter often show great diversity in 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: the infant parasite rate determined in children of this age group is of value as an index of the liability to contract infection in a given locality. The adult parasite rate is also important for appraisal of the degree of tolerance of the infection in the community.

The same considerations hold good for the parasite rate as for the spleen rate in regard to the living conditions of the children examined; if the rate is computed from school children, this should always be stated. Any possibility that the children may have received antimalaria medication should be noted.
Parasite count

48. In computing the parasite rate no account is taken of the fact that the numbers of parasites found in the blood may show great variation. The number of parasites per cubic millimetre of blood (or in relation to any other arbitrary unit expressing the volume of blood examined) is the parasite count.

49. For accurate enumeration of parasites a suitable technique must be used—for example, small measured quantities of blood spread over a known area, or the fowl-corpuscle method of Sinton (1924). The following are methods by the use of which approximate results may be obtained:

1. Count the parasites seen in a thick or a thin film in a given examining time.
2. Count 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. Count the parasites in relation to the number of (a) red cells or (b) leucocytes seen in each field, using an ocular with square aperture of suitable area. Method (a) is applicable only to thin films where the red cells are left intact, and method (b) to thick films where only the leucocytes show a sufficiently even distribution to be counted.

If thick films are made of a roughly standardized thickness, counts obtained by examining a given number of fields may also be roughly expressed in numbers of parasites per cubic millimetre. The counting of leucocytes per cubic millimetre of the blood enables a better quantitative result to be given. Another method is to count the parasites in 100 fields of a thin film; since the rough average number of red cells in the field for a given objective and eyepiece can be ascertained, the results may be expressed as parasites per cubic millimetre, provided that the number of erythrocytes per unit volume of the blood is known.

Parasite density

50. The parasite density gives an indication of the collective degree of infection in a sample or a community. The use of the arithmetic mean of the parasite counts in estimating the parasite density is unsatisfactory because of the large variations in the individual parasite counts; if one infection is of very great magnitude it may grossly swamp the mean of a majority of much lower counts. Therefore it is preferable to calculate the parasite density as a geometric mean, i.e., the \( n \)th root of the product of \( n \) number of counts (the computation of the geometric mean is greatly facilitated by reducing it to its logarithmic form). A convenient alternative to the geometric mean is to draw up a table of frequency distribution, arranging the
data according to magnitude, divided into groups or classes. The usual method of setting out the frequency distribution (with the numbers in any given class as ordinates and the measurement specifying the classes as abscissae) is often less useful in this situation than an array (infections arranged in order of magnitude spaced at regular intervals along the base line). Such spacing is preferably based on a geometrical progression, using, for instance, the factor 2, as follows:

<table>
<thead>
<tr>
<th>Class</th>
<th>Parasite count per mm$^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Less than 100</td>
</tr>
<tr>
<td>2</td>
<td>101 - 200</td>
</tr>
<tr>
<td>3</td>
<td>201 - 400</td>
</tr>
<tr>
<td>4</td>
<td>401 - 800</td>
</tr>
<tr>
<td>5</td>
<td>801 - 1,600</td>
</tr>
<tr>
<td>6</td>
<td>1,601 - 3,200</td>
</tr>
<tr>
<td>7</td>
<td>3,201 - 6,400</td>
</tr>
<tr>
<td>8</td>
<td>6,401 - 12,800</td>
</tr>
<tr>
<td>9</td>
<td>12,801 - 25,600</td>
</tr>
<tr>
<td>10</td>
<td>25,601 and over</td>
</tr>
</tbody>
</table>

This classification was used for surveys in West Africa (Bruce-Chwatt, 1958). It permits calculation of the positive parasite-density index by use of the weighted frequencies—that is, by multiplying the frequencies determined for each class by the class number, adding all the products, and dividing the total by the total number of positive slides.

Recording and interpretation of results

51. So far, infections have been considered without reference to the fact that they arise sometimes 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 each species is counted separately. If infections by a single species markedly predominate in any one area, the parasite rate will reflect more or less satisfactorily the number of infections by that species. The question of plurality of infections must be considered, however, in relation to terminology. Such findings should be recorded separately (Fig. 6), since they are of epidemiological significance.

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 arising from any given species in the total number of infections found is the relative prevalence of infections by that species. A statement giving in some recognized order the relative proportion or percentage of the various species found in the total number of infections is the parasite formula. In a blood slide showing a mixed infection, each species found is counted separately.
Let us suppose, for example, that in a group of slides of 100 children, 40 show *P. vivax*, 20 *P. falciparum*, and 2 *P. malariae*. The parasite rate would of course be 62%. The vivax infection rate would be 40%; its relative prevalence would be \((40/62) \times 100\), or 64.5%; the parasite formula would be: *P. vivax* 64.5%, *P. falciparum* 32.3%, *P. malariae* 3.2%. If, however, 10 children have mixed vivax-falciparum infections, the parasite rate would be only 52%, but as the number of infections with separate species remains 62, the species infection rate, the relative prevalence and the parasite formula would remain the same.

For proper recording of data obtained in the course of malarioriometric surveys the use of standard forms is necessary. Two such forms are shown in Figs. 5 and 6. The form shown in Fig. 5 may be used in the field when the palpation of spleens and the collection of the corresponding blood slides are carried out. The column for "Result of blood examination" is filled in by the laboratory worker after he has stained and examined the numbered slides. Fig. 6 is filled in at the laboratory from the results of blood examinations together with the data supplied on the Fig. 5 form; it thus gives a consolidated record of the persons examined, by age groups, localities or other categories.

**FIG. 5. INDIVIDUAL SPLEEN/BLOOD RECORDS**

| Place: ........................................... | Project: ...........................................
| Date: ........................................... | Investigator: ....................................
<table>
<thead>
<tr>
<th>Serial No. of slide</th>
<th>Name</th>
<th>Age</th>
<th>Sex</th>
<th>Spleen class</th>
<th>Result of blood examination</th>
<th>Remarks</th>
</tr>
</thead>
</table>

52. In assessing the significance of malarioriometric rates and indices it must be remembered that those based on the spleen findings and those derived from blood examinations do not measure the same characteristics. The positive blood film is the proof of an existing infection, while the enlarged spleen reflects the response of the organism to it. Thus the figures must be regarded
**FIG. 6. CONSOLIDATED SPLEEN/BLOOD RECORD**

<table>
<thead>
<tr>
<th>Age group</th>
<th>No. of spleens examined</th>
<th>Spleen class</th>
<th>No. of blood films examined</th>
<th>No. of positive blood films</th>
<th>Malaria infections</th>
<th>P. vivax or P. ovale</th>
<th>P. falciparum gametocytes</th>
<th>P. falciparum asexual plasmodia</th>
<th>Class of parasite count</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

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47
as complementing each other, and whenever possible they should be assessed together for the population concerned.

The results of a malarialometric survey must always be interpreted with caution. Each worker will naturally be guided by his own past experience and that of others. In considering the data special attention should be given to the age distribution of the spleen and parasite rates, to the average-enlarged-spleen value, to the parasite density, to the relative frequency of the different species of parasites, and to relevant factors in the physical, biological, and socio-economic environment.

**Malaria eradication programmes**

The carrying out of a malaria eradication programme, according to the WHO Expert Committee on Malaria (1959),

"... requires continuous [epidemiological] evaluation, starting either before or in the very earliest part of the preparatory phase and continuing until the end of the programme ... In the early stage the objective is epidemiological study ... concerned with malaria as a static condition. Techniques suitable for the assessment of a relatively static condition, such as have become traditional in malaria surveys, are indicated. Once the phase of attack starts, however, evaluation must concern itself with malaria as a dynamic condition which is rapidly diminishing and later disappearing, and techniques adapted to this dynamic state, many of them relatively new, must be adopted."

The new techniques mentioned above have become firmly established in malaria eradication activities, and a number of new relevant terms are now accepted.

**53.** The malarialometric survey is the best method for the delimitation of a malarious area and the assessment of the endemic prevalence during the preparatory phase of the malaria eradication programme. The results of this type of survey conducted in samples of populations are expressed as malarialometric rates indicating the proportion of persons infected with malaria at a given time, usually in selected groups of a defined population. Malarialometric rates are still useful during the early part of the attack phase in an eradication programme because they indicate the gross reduction of malaria. Experience in eradication programmes, however, has shown that malarialometric surveys cease to be sufficiently sensitive when parasite rates have decreased to a level between 1% and 3%. In well-conducted and successful malaria eradication programmes this point may be reached as early as the second year of the attack phase.

Some authors refer to malaria as "responsive" when its amount is rapidly reduced ("by crisis") soon after the beginning of the attack phase. If the reduction of malaria is slow and gradual ("by lysis") in spite of total coverage by spraying it may be referred to as "refractory" malaria.
54. When the malarialometric surveys are no longer sufficiently sensitive it is necessary to change to a method of evaluation that measures malaria not in a static, periodic way but in a dynamic, continuous way, and not in a sample but in the whole population. The principal method used for this type of evaluation is malaria case detection. A malaria case is here defined as an occurrence of malaria infection in a person in whom, regardless of the presence or absence of clinical symptoms, the presence of malaria parasites in the blood has been confirmed by microscopic examination. The principal method of case detection, however, is the continuous screening of the total population for fever cases, from whom blood slides are taken. Afebrile cases (“suspected cases”, “collateral cases”) are usually detected during epidemiological investigations carried out in the surroundings of fever cases which have been confirmed as malaria cases. Malaria case detection and epidemiological investigation of the cases found are integral parts of surveillance operations, which constitute the principal activity in the consolidation phase of malaria eradication. The methods and terminology of surveillance operations are discussed in Chapter VI.

55. The results of malaria case detection furnish a true measure of malaria incidence. In malaria eradication this measure is usually expressed as the annual parasite incidence, which gives the proportion (per thousand of population) of malaria cases detected during one year. The level of annual parasite incidence is the most important criterion for the progress of a malaria eradication programme after its second year.

56. The measurement of the annual parasite incidence is, however, only valid if based on fully efficient case detection, that is, the case-detection mechanism must achieve total geographic coverage and adequate continuity in time. For the judgement of the adequacy of case detection a number of operational data must be considered, but a rough quantitative indication can be obtained by counting the total number of blood slides taken and examined in the population during a specified period. In malaria eradication this is usually expressed as the annual blood-examination rate. It is generally accepted that this rate, in an area with long seasonal transmission, should be not less than 10%, provided that the quality of the case-detection routine is above reproach.

57. In malaria eradication an accurate assessment of the origin of the cases detected is just as important as the quantitative measurement expressed in the annual parasite incidence and based on case detection. It is therefore essential, particularly during the consolidation phase, to classify by origin of infection all cases detected. The standard terms for classification of malaria cases by origin are: “indigenous”, “relapsing”, “imported”, “induced” and “introduced” (see para. 35). The strongest evidence of achieved eradication, at the end of the consolidation phase, is a register
of all malaria infections discovered during the preceding three years, establishing beyond reasonable doubt that every case was imported, relapsing, induced or introduced (WHO, Expert Committee on Malaria, 1961).

The ecological approach in malaria eradication

An ecological approach to the study of a disease or the methods needed for its elimination is based on investigation of the conditions necessary for its transmission, that is, the relations among the pathogenic agent, its host (or hosts) and the environment. The scope of such an approach is extended at times from the relation between the organisms and the environment to the study of various types of environments as such.

Two main terms connected with the ecological approach in malariology, "malaria focus" and "epidemiological zone", are of particular importance in assessing the situation in advanced phases of malaria eradication.

58. A malaria focus exists whenever a human community and anopheline population maintain the existence of the population of malaria parasites. For the epidemiologist, a focus is the basic epidemiological unit in which the epidemiological process (transmission of the agent, reproduction of cases) takes place. The human community and mosquito population are connected with a definite area, and various types of malaria foci may be distinguished according to the ecological characteristics of the area.

The classification of malaria foci may be based on various considerations,\(^1\) but for operational purposes the classification related to the interruption or renewal of malaria transmission is the most useful. Thus one may speak of residual foci and new foci, with various subclassifications of these as follows:

<table>
<thead>
<tr>
<th>Type of focus</th>
<th>Epidemiological characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residual:</td>
<td></td>
</tr>
<tr>
<td>Non-active</td>
<td>Transmission interrupted; no indigenous cases but possible occurrence of relapsing ones</td>
</tr>
<tr>
<td>Active</td>
<td>Transmission not interrupted; occurrence of relapses and new (indigenous) cases</td>
</tr>
<tr>
<td>New:</td>
<td></td>
</tr>
<tr>
<td>Potential</td>
<td>Presence of imported cases; no evidence of transmission, but its renewal possible</td>
</tr>
<tr>
<td>Active, 1st degree</td>
<td>Renewed transmission; imported cases and introduced cases present</td>
</tr>
<tr>
<td>Active, 2nd degree</td>
<td>Renewed transmission; imported cases and indigenous cases present</td>
</tr>
</tbody>
</table>

\(^1\) Thus a focus may be qualified as stationary if a community is living in a permanent locality, or migratory if the community is a migratory one. Depending on the existence and degree of exchange of parasites between adjacent malaria foci (through an exchange of mosquitoes or the movement of infected persons), one may also refer to isolated or conjugated foci.
The term "focus" should not be applied to a locality in which parasites are found in one or more permanent or temporary inhabitants but where the conditions for malaria transmission do not exist; here the term "pseudo focus", used with proper qualification, has been suggested.

59. The totality of malaria foci in a territory constitutes a malarious area. If a malarious area contains various ecological types of malaria foci it may be divided into several reasonably homogeneous epidemiological zones. An epidemiological zone is defined as the total territory (whether in one country or in several) characterized by a more or less uniform level of malaria prevalence in the majority of its malaria foci and by similarities of environment (topography, climate, vegetation), vector ecology and human habits. An epidemiological zone is often classified according to its main environmental features, hence terms such as "mountain-stream zone", "foothill zone", "coastal zone", "irrigated zone" etc. may be used.¹

¹ Writers in Russian use the term "landscape epidemiology" for such a method of classification.
III. ENTOMOLOGY IN RELATION TO MALARIA

60. Out of about 2500 species of mosquitoes,¹ over 300 named species of Anopheles ² are known, not including recognized subspecies and other infra-specific groups. The subfamily Anophelinae is one of three into which the family Culicidae (or true mosquitoes) is divided. All but a very few rare forms are included in the genus Anopheles, of which several subdivisions are recognized. Most of the species within this genus are not sufficiently closely associated with man to be important as malaria vectors, but the females of over 60 species are recognized as vectors of human malaria. The geographical, seasonal, or ecological distribution of Anopheles is therefore not necessarily related to the presence of malaria, and anophelism without malaria is not only possible but may represent the final outcome of malaria eradication, in which the elimination of the vector is not primarily intended.

The basic taxonomic unit, the species, known under its binominal designation, is of fundamental importance in systematics, in experimental work and in field work. Named subspecies of a number of species are recognized. They represent populations that became geographically isolated from the parent species and have undergone taxonomically significant genetic divergence. The subspecies are given a trinominal designation, e.g., A. minimus minimus, and A. minimus flavirostris (see Chap. VII).

Descriptions of genera and species are published in separate papers in scientific journals, in compendia, synopses, revisions and monographs. Monographs generally deal with one zoographical region or smaller geographical areas; as a result of the rapidly increasing amount of new information gathered by systematists, many monographs tend to go quickly out of date. Synoptic catalogues such as that by Stone et al. (1959) are of more lasting value.

Specimens may be identified by the use of taxonomic keys prepared for this purpose. Most keys are dichotomous, so that morphological characters are displayed as pairs of alternatives; the worker proceeds from one couplet to another by a process of elimination and gradually narrows down the number of possibilities for correct identification. There are also simple pictorial keys, useful for less experienced workers. An identification ob-

¹ "Mosquito", a word of Spanish or Portuguese origin but probably of Sanskrit derivation, has been used in English (with various spellings) for nearly four centuries; according to Christopher's (1966), it was quoted in Hakluyt's Voyages (1589) from an earlier source.

² From the Greek on (prative) and ophelos ("advantage" or "use"). The term was introduced by Meigen in 1819.
tained from a key must be regarded as preliminary, especially in the case
of rare species, and any doubtful specimens should be checked against a full
description.2

Considerable differences in vector efficiency may exist between two sub-
species or between other infraspecific categories of *Anopheles*. Moreover,
genetic factors may greatly change the behaviour of a local species and
its response to insecticides.

**Stages of growth and development of the mosquito**

**Metamorphosis**

**61.** The successive forms assumed during metamorphosis are the egg,
larva, pupa, and adult or imago (plural: imagos or imagines). The unde-
developed egg in the ovary is called the ovum. The liberation of the larva
from the egg is referred to as hatching (eclosion). The casting of the suc-
cessive larval skins ("pells") 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 larval stages ("instars") that, while the body of the larva
grows so that its size in any stage may change considerably, the head remains
unchanged and therefore offers a ready means of determining the stage.
The fourth ecdysis, which succeeds the final or completed larval stage
(fourth-stage larva), results in the formation of the pupa (pupation), followed
in due course by emergence of the imago. Deposition of eggs by the female
constitutes egg-laying, or oviposition. The site chosen for oviposition and
subsequent development of the larvae in nature is the breeding place, also
known to ecologists as the larval habitat. The set of eggs (which may be
examined or subsequently bred out for examination) deposited by a female
at any one oviposition is referred to as a batch.

**62.** In connexion with artificial rearing, the statement that a species has
been reared in captivity may mean simply that eggs, larvae or pupae have
been collected in the field, with subsequent emergence of the adults in the
laboratory, or it may indicate that fertilization has been brought about under
laboratory conditions with subsequent development. In order to distin-
guish between the two cases, it is suggested that "bred out" in captivity
be used for the first, and "reared" in captivity for the second. A population
of a species of mosquito maintained in the laboratory through more than
one generation is a colony.2 Anopheles are reared in laboratories today not

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2 The principles of identification of *Anopheles* will be found in Puri (1957), in Gordon & Lavigne (1962) and in a chapter by Mattingly in the *Practical Guide for Malaria Entomologists in the African Region of WHO* (de Meillon, 1961).

2 Some workers distinguish between a "mosquito colony" and a "mosquito culture," the latter term referring to a collection of live mosquitoes of a species reared in the laboratory but dependent on regular
supplies of larvae or pupae from natural breeding places.
only to maintain strains of a species but also to isolate susceptible and resistant fractions of a mixed population and to study the genetic basis of resistance.

**Gonotrophic cycle**

63. A gonotrophic cycle is generally understood as one complete round of ovarian development of the female mosquito from the time when the blood meal is taken to the time when the fully developed eggs are laid. This term is extended by many workers to the complete period of development until the time when the next blood meal is taken. As many vectors can feed on the same night on which they have oviposited, the two different conventions will give much the same estimate of the duration of the cycle. There are unusual cases, however, in which there is a gap of 24 hours or more between oviposition and a subsequent blood meal, in which case the second

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**FIG. 7. STAGES OF BLOOD DIGESTION AND OVARY DEVELOPMENT**

(AFTER SELLA, 1920)

1 — Empty female, ovaries not developed

2 — Freshly blood-fed female, ovaries not developed

3 — Blood meal darker, area of 2 sternites and 4-5 tergites free of blood

4 — Blood very dark, area of 2½-3 sternites and 5-6 tergites free of blood

5 — Blood black, area 2½-3½ sternites and 6½-7¼ tergites free of blood

6 — Remaining blood black only on the ventral side, the rest of the abdomen occupied by developing ovaries

7 — No blood visible, eggs fully developed
convention will produce a longer cycle. The epidemiological significance of this is obvious. The duration of the gonotrophic cycle depends on environmental factors and on the species of mosquito; in tropical conditions the completion of the gonotrophic cycle may take no longer than 48 hours. Normally the gonadal development follows the blood meal (gonotrophic concordance); when the ovaries remain in an undeveloped state while the insect continues to take blood meals, the condition is described as gonotrophic dissociation or gonotrophic discordance.

Females which have not previously oviposited are said to be nulliparous, those which have oviposited at least once are parous, while those which have oviposited more than once are multiparous.

64. In the ovary of the nulliparous female anopheles (recently emerged and unfed) no development takes place until the mosquito obtains the blood meal. Development of the ovarioles in the ovary then proceeds as the meal is digested and culminates in oviposition. Two blood meals may be necessary for the completion of the first gonotrophic cycle, but one blood meal normally suffices in subsequent cycles. A blood meal, until digested, is evidenced by the presence of red, and later dark brown, blood in the midgut. Several stages of blood digestion and of the appearance of the abdomen of the mosquito consequent on ovary development and defined by Sella (1920) are shown in Fig. 7. A female containing blood in the gut is commonly referred to as a fed female; one which has not fed, or in which the blood has been completely digested, as an empty female.

As the blood meal is digested the ovaries enlarge. If the ovaries are perceptibly enlarged, the insect is designated a gravid female. Fig. 8 shows the progressive changes in the ovary and ovarioles, classified by Christophers (1911) in five stages of the development of the follicle into a mature egg as follows:

Stage I: ovum without marked granules
Stage II: granules present and occupying up to half the follicle
Stage III: granules occupying over half the follicle, which, however, is not elongated
Stage IV: follicle elongated or having shape of mature egg, but superficial structures not evident
Stage V: egg fully formed and floats visible

A complete description of the structure of the mosquito ovary and of the changes taking place during oogenesis, ovulation and oviposition is found in a paper by Bertram (1962), which also contains a glossary of relevant morphological terms.

The changes that take place in the genital tract of the female mosquito subsequent to the completion of the gonotrophic cycle are of considerable practical importance, as they are used for the assessment of the age of the female anopheles.
FIG. 8. STAGES OF THE DEVELOPMENT OF THE FOLLICLE INTO A MATURE MOSQUITO EGG (AFTER CHRISTOPHERS, MODIFIED BY PURI, 1907)

I
(a) Earliest stage of follicular tube showing immature follicles.
(b) Further stage of follicular tube with primary follicle a little advanced, showing formation of outer envelope of follicular cells, nurse cells, and ovum. Nucleus of ovum is differentiated from nuclei of nurse cells, but protoplasm of ovum is devoid of yolk granules.

II
(a) Beginning of stage II, showing deposition of fine yolk granules in protoplasm of ovum.
(b) Follicle nearing end of stage II; yolk granules abundant, nearly obscuring nucleus; ovum occupying about half the follicle.

III
(a) Follicle at commencement of stage III, nucleus of ovum completely obscured by yolk granules.
(b) Follicle near end of stage III, ovum occupying about \( \frac{1}{4} \) of follicle; \( f_2 \) at stage I.

IV
(a) Follicle early in stage IV.
(b) Follicle near end of stage IV, taking shape of \( \frac{3}{4} \) mature egg.

V
Follicle in stage V, floats (fl) developed; \( f_3 \) at commencement of stage II.

Stages III, IV, and V shown at \( \frac{1}{4} \) the scale of stages I and II.
Age-grading

65. Determination of the age of female mosquitoes is of importance for full understanding of the epidemiology of malaria and for assessment of the efficacy of anti-anopheline measures, most of which aim at shortening the average lifespan of the population of the malaria vector. The concept of physiological age determined by the number of gonotrophic cycles undergone by a female mosquito is basic. By means of age-grading, using any reliable method, it is possible to determine the age composition of the mosquito population and to find out the proportion of females which are in the epidemiologically dangerous age.

A number of age-grading methods were formerly used. The earliest one classified the age of the mosquito by the degree of wear of the wing; later methods were based on such physiological characteristics as the presence of meconium in the midgut, the presence of a "mating plug", fertilization, and enlargement or other changes of the ampulla of the common oviduct. At present two methods are increasingly used:

FIG. 9. APPEARANCE OF AN OVARIOLE OF A MOSQUITO DURING SUCCESSIVE GONOTROPHIC CYCLES (SIMPLIFIED, AFTER BERTRAM, 1962)

(A) From nulliparous female, with primary follicle at early stage III and second follicle at stage I; no dilatation.

(B) From parous female, after first oviposition; former primary follicle represented by dilatation (D1) containing follicular relic; second follicle at stage II.

(C) From parous female, after two ovipositions, showing two dilatations (the second containing a follicular relic) representing positions of former primary (first) and second follicles.
1. A simple technique for distinguishing between parous and nulliparous female anophelines by examination of the tracheoles of the ovaries permits assessment of the nulliparous-to-parous ratio, from which the probability of survival of mosquitoes and therefore their average longevity can be calculated.

2. A more elaborate technique is based on the dissection of the ovaries to count the number of dilatations left in the ovarioles subsequent to each ovulation and oviposition. The number of dilatations found usually corresponds to the number of gonotrophic cycles, and this gives more direct evidence of the physiological age of the females (Beklemishev et al., 1959; Detinova, 1962; see Fig. 9).

**Life history and behaviour**

**Breeding places**

66. The collections of water in which anopheline larvae of any species are found are the breeding places (larval habitats) of that species. These may be temporary or permanent, natural or artificial (man-made). Temporary breeding places found dry at the moment of inspection and likely breeding places not actually showing larvae are referred to as potential breeding places. An artificial breeding place constructed with the purpose of collecting mosquito eggs or larvae is a trap breeding place. The number of adult mosquitoes produced from the breeding place per unit of time and surface is the anopheles output.

**Dispersion**

67. The spread of anopheles from their breeding places, usually in search of food, constitutes dispersion. Distance of dispersion is the mean distance or the maximum distance, as the case may be, to which mosquitoes actively disperse from their breeding places. The distance which may be covered under some special conditions of migratory flight, 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 referred to as infiltration of an area or an influx into it. When anopheles are brought into an area by vehicles or otherwise transported, this is described as passive dispersion. When anopheles are carried long distances by wind, the phenomenon may be described as wind dispersion.

It is desirable to distinguish between the distance a mosquito can fly at a single effort ("flight range") and the total distance it may cover in many such flights ("distance of dispersion"). The term "effective flight range"
refers to the distance travelled from a breeding place by the females of a
given species in numbers sufficient to maintain endemic malaria or to cause
an epidemic.

The nuptial flight or dance, when males gather together and copulate
with the females in the air, is known as swarming.

**Feeding and resting habits**

68. The source from which the 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. Day resting places may be indoors in human habitations (houses),
places where animals are kept (stables, as a general covering term), outlying
unoccupied sheds and the like (shelters), or out of doors in undercut banks,
dergrowth, caves, etc. (natural shelters).

The tendency of mosquitoes to rest indoors is known as endophily; the
opposite tendency to shun enclosed spaces whether by day or by night is
termed exophily. Both terms are relative and should be qualified. The relative
tendency of mosquitoes to feed indoors is known as endophagy, the
opposite tendency is exophagy.

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

The blood meal may be obtained from man or from cattle or other
animals. The terms "anthropophilic" and "zoophilic" have been used for
species of *Anopheles* to indicate, respectively, a supposed preference for
feeding on man or cattle. Such terms can give rise to misconceptions unless
it is understood that they are relative and always require qualification.
Actually, anopheles usually include among possible hosts a number of ani-
imals, including man, the order of preference for different hosts ("host
preference") varying with the different species. This preferential tendency
must be distinguished from mere readiness to feed on any particular host
when no other is available.

The proportion of freshly fed anopheles giving a positive precipitin
reaction for human blood is the human blood index (often, less correctly,
called human blood ratio) for the particular conditions in which capture
was made. Such an index gives some indication of the degree of host pre-
ference for man under those circumstances and is closely bound up with the
extent to which a species in given conditions acts as a vector. The human
blood index has also been termed the anthropophilic index; the host prefer-
ence index refers to any specified host. A decrease in the proportion of mos-
quitos feeding on man when non-human hosts become available is known as animal deviation.

The terms "tropism" and "taxis" are applied to various reflex urges causing a mosquito to be attracted or repelled or to fly in a given direction.

The study of the act of feeding of the mosquito has given rise to terms such as "biting cycle" and "biting frequency" ("biting rate"). (The use of the word "bite" is inappropriate with regard to the blood-feeding mechanism of mosquitoes but is sanctioned by common usage.) The term "maxillary index" refers to the arithmetic mean of the number (per maxilla) of teeth on the two maxillae of the female mosquito.

Other behaviour characteristics

69. Although in certain species of some other genera the necessary store of nutriment for the eggs is accumulated in the larval state, so that oviposition by the imago occurs without previous feeding ("autogenous behaviour"), anopheles, and indeed most other mosquitoes, always require a blood meal before oviposition can take place.

Certain species tide over the cold season ("overwintering") as egg, larva, or adult; adult overwintering is termed "hibernation". When the female stores fat in her body 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 the winter is over.

Special adaptation taking place in surviving a dry hot season is referred to as aestivation. Any cessation or marked slowing down of development in response to adverse environmental conditions is known as diapause.

The branch of biology devoted to the study of seasonal periodic biological events is known as phenology.

The anopheles population

70. The total number of anophelines in a village and its immediate surroundings is the anopheles population. The number of anophelines per person, per room, per house, per square foot of resting surface, per time unit, or per standard trap is the anopheline density. Estimation of the proportion of males and females, of fed and empty, of fertilized and unfertilized females, etc., gives the anopheles population composition. The assessment of the mean age of such a population is carried out by means of age-grading.
Periodic sampling of adults of the mosquito population of a locality is carried out by hand-capture or spray-capture in capture stations. Mosquitoes are collected in houses, huts, stables or, out of doors, in natural harbours or artificial shelters. Methods include the use of bed-net traps and of human or animal bait.

71. Trap huts (experimental huts) are usually huts of simple design, often built of the same material as local habitations, which are modified in such a way that mosquitoes may be trapped as they enter or leave ("inlet window traps" or "outlet window traps"). Mosquitoes entering the hut have free access to the bait, which may be human or animal. The outlet window traps are of particular importance in estimating what proportion of mosquitoes leave the hut with or without feeding, either as a normal habit or as a result of insecticide treatment of the hut. The effect of different insecticides and different dosages applied to the hut is estimated by making a series of counts of the mosquitoes in the hut and in the window trap and comparing these figures with those recorded in an untreated hut. The mosquitoes counted as dead include those found dead on the floor of the hut; those found dead in the window trap; those found alive in the window trap but dying after 24 hours; and those found alive in the hut but dying after 24 hours. Live mosquitoes are those found alive in the hut which survive 24 hours and those found alive in the window trap which survive 24 hours. Further subdivision of these groups into categories such as blood-fed and unfed makes possible an even more critical assessment of the effect of insecticide treatment on vector behaviour and mortality.

Occasional or regular collections of larvae (larval surveys) give a picture of the type and amount of anopheline production in the area. Such surveys show the association between different species of Anopheles as well as various physical and other characteristics of the breeding places. Larvae are collected by methods such as dipping and netting.

Infection in anopheles

72. The vector efficiency of a mosquito depends on a number of factors, some related to the species of Anopheles and of the malaria parasite, others to environmental conditions. One commonly refers to the main or principal vector and to the secondary vector or vectors.

An anopheles which, on dissection, shows oocysts on the stomach wall is infected; when it shows sporozoites in the salivary glands, it is infective. The percentage of female anopheles caught in nature showing sporozoites in 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 determined species, and the number of mosquitoes dissected should
be indicated. Information as to the source of capture (e.g., houses, stables, natural shelters) is important. In highly endemic areas considerable variation in the sporozoite rate may be due to seasonal increase or decrease of the mosquito population, and in such a case some statistical assessment of the significance of the rate is necessary.

The percentage of anopheles caught in nature showing either sporozoites in the glands or oocysts in the stomach is known as the anopheline infection rate or rate of natural infection (but not all sporozoite or oocyst infections are of human origin). The percentage of experimentally infected anopheles showing either sporozoites in the glands or oocysts in the stomach is the rate of experimental infection.

The term "average infective density" was used by Davey & Gordon (1933) to designate the average number of female anopheles found with sporozoites in the glands per room per day. This is a product of anopheline density and infectivity, recorded as a result of house-to-house search and room-captures carried out over a considerable period. The inoculation rate per person per time unit may be estimated when the number of persons per room and the biting frequency of anopheline vectors are known, but such an estimate may be reliable only for vector species very closely associated with human dwellings for both resting and feeding.

Response of mosquitoes to insecticides

73. Mosquitos have been used in applied entomology for evaluation of the biological effectiveness of insecticide deposits. Such bioassay tests, in which the insects are deliberately exposed to the insecticide, are a simple and useful tool in practical malariology, but their results always require careful interpretation, because the conclusions derived from laboratory bioassay tests are not necessarily applicable to field conditions. Results obtained by means of sprayed houses with window traps and other devices will give a better idea of the effectiveness of insecticides under field conditions, but the value of an insecticide in malaria eradication can be finally assessed only from epidemiological evaluation.

74. Over a period of years evidence has been accumulating of the development in many species of insects of a changed response to insecticides used in public health practice (Brown, 1958). The term "resistance" is generally used whenever insecticides seem to lose their previously evident effect. This usage is, however, unsatisfactory when dealing with a complex biological phenomenon requiring a precise definition.

75. Quantitative methods for the assessment of the susceptibility of each relevant species or population of insects were proposed by WHO as early
as 1954 but were introduced only relatively recently. These methods permit the definition of insecticide resistance as a developed characteristic consequent upon the application of the insecticide. According to the WHO Expert Committee on Insecticides (1957), the term "insecticide resistance" refers to "the development of an ability in a strain of insects to tolerate doses of toxicants which would prove lethal to the majority of individuals in a normal population of the same species". This definition describes physiological resistance, whose mechanism is complex and still not fully understood, though it may depend on such factors as decreased penetration of the toxicant through the cuticle, increased storage, enzymatic detoxification, and decreased sensitivity of the nervous system (WHO Expert Committee on Insecticides, 1958).

76. In every type of insecticide test, whether mosquitoes or other insects are used, the check (or comparison) mortality \(^1\) of a representative sample not exposed to the toxic action must be assessed in order to evaluate the effect of factors unrelated to the insecticidal action. In this way the true level of insect mortality due to the action of the toxicant can be gauged, using Abbott's formula for correction of results. The median lethal dose (LD\(_{50}\)) or concentration (LC\(_{50}\)) is a useful parameter for the comparative appraisal of the amounts of insecticide tested in well-defined experimental conditions, but other parameters such as the minimum absolute lethal dose or concentration (LD\(_{100}\) or LC\(_{100}\)) are also used (WHO Expert Committee on Insecticides, 1960).

The appearance of resistance is due to the selection pressure exerted by an insecticide when, in the population exposed to it, some individuals carrying particular hereditary factors survive in increasing proportion from one generation to another, while those not possessing this factor are eliminated. Since the genes for resistance may be distributed among mosquitoes according to Mendelian laws of inheritance, the population with the resistant character will be composed of both homozygous and heterozygous individuals, that is, some fully susceptible to a given dose of the toxicant and some fully resistant to it, as well as some hybrids, which in certain cases (as in dieldrin resistance in A. gambiae) show an intermediate tolerance. In practice these grades of response can be distinguished by the use of discriminating doses of a specific insecticide. In genetic studies the laws of inheritance of the resistant character are investigated by crossing or back-crossing individuals of given strains of the same species.

77. Physiological resistance to the chlorinated hydrocarbon insecticides seems to be of two distinct types: (1) resistance to DDT and its analogues

\(^1\) The word "control" is commonly used to designate the standard against which comparisons are made by experiment. In circumstances where the use of this word might lead to confusion with "control" in the sense of "malaria control", it is preferable to replace it by the words "check" or "comparison" in such terms as "comparison groups" or "check mortality".
such as methoxychlor, and (2) to the cyclodiene derivatives such as 
dieldrin and chlordane and to lindane (gamma-BHC). There is ample 
evidence of the different biochemical and genetic nature of these two types 
of physiological resistance. The conventional term “cross-resistance” 
is often used when referring to resistance to an insecticide (such as gamma- 
BHC) following or accompanying the development of resistance to another 
insecticide (such as dieldrin) within the same group (of cyclodiene deriv-
atives). When resistance develops, in exceptional cases, to one or more 
insecticides of different types or groups, the term “double (or multiple) 
resistance” is used.

The ability of a species not previously exposed to a given insecticide to 
survive higher doses of it than are generally lethal to other zoologically 
related and normally susceptible species is known as natural or innate 
insecticide tolerance. An increased insecticide tolerance in a strain or a 
population of a species may be seasonal—e.g., related to pre-hibernation— 
or it may be due to other conditions which lower the “normal” level of 
susceptibility to any insecticide (“vigour tolerance”). At times, however, 
such an increased insecticide tolerance may be the sign of incipient physio-
logical insecticide resistance (Busvine, 1957).

78. Some insecticides, such as DDT, exert an irritant effect on mosquitoes, 
interfering with their resting habits and stimulating them to fly. It has 
been reported that in certain strains of insects an increased tendency to 
avoid actual or possible contact with the insecticide develops. This beha-
vioral response, still not fully understood or investigated, is known by the 
term “insecticide avoidance”; “protective avoidance” has also been used. 
It may be natural, when characteristic of a species or strain; or it may be 
aquired or developed after exposure of a number of generations to the 
insecticide. The acquired type has also become known as “behaviourist 
resistance” (WHO, Expert Committee on Insecticides, 1957 and 1960).

Methods of control of the malaria vector

79. Many measures of malaria prevention (“malaria prophylaxis”) and 
mosquito control are known and listed in standard textbooks. A sound 
classification of these measures was proposed by Russell et al. (1946) and 
need not be repeated here. Control measures aimed at the protection of the 
community from bites of anophelines independent of the destruction or pre-
vention of breeding of these insects (for example, by screening or by the use 
of repellents) constitute protection or protective control measures. Meas-
ures directed specifically against the vector are termed aggressive control 
measures. They may be used against (1) the aquatic stages (larval control
or antilarval measures), and (2) the adult mosquitoes (adult control or anti-
imaginal measures).¹

Larvicides are insecticidal substances used for killing the aquatic stages of mosquitoes. An imagicide (occasionally called "adulticide") is used for destroying insects in their adult stage. Imagicides are of two types: (1) knock-down insecticides with a rapid and short-lived action used for space-spraying, and (2) residual insecticides, which produce on the sprayed surface a deposit which maintains the toxic effect for a considerable time and acts on the vector through direct contact. A new type of insecticide with a prolonged fumigant effect not based on direct contact of the insect with any sprayed surface is now coming into use.

¹ In the past when control measures were 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 constituted species sanitation, species control, or species eradication.
IV. CHEMOTHERAPY

80. Terminology in chemotherapy of malaria must be based on considerations of the action of antimalarial drugs, their application for treatment or prevention of the disease, and their place in different phases of malaria eradication.

Some confusion in the terminology is due to inconsistent use of certain terms; moreover, a number of unsatisfactory or incorrect terms have been in use for a long time and cannot easily be changed even though better terms are needed. The monograph *Chemotherapy of Malaria* (Covell, Coatney, Field & Singh, 1955) adopted the definitions of terms presented in the 1953 *Malaria Terminology*. Some changes were suggested in the report of the WHO Technical Meeting on Chemotherapy of Malaria (1961a).

The activity of an antimalarial drug is usually restricted to one or two stages of the life cycle of the parasite. It is therefore convenient to define the action of an antimalarial in relation to its specific field of activity. According to the stage of the life cycle which is mainly affected, antimalarial drugs may be classified in one (or several) of the groups (see Fig. 10) discussed below.

81. Primary tissue schizontocides ("causal prophylactics") act on the pre-erythrocytic stages of the parasite (primary tissue forms or primary exoerythrocytic forms) and thus completely prevent erythrocytic infection.

82. Secondary tissue schizontocides ("anti-relapse drugs", "radically curative drugs") act on the secondary exoerythrocytic stages (secondary exoerythrocytic or secondary tissue forms) of *P. vivax*, *P. malariae* and *P. ovale* and thus are able to achieve radical cure of these infections.

83. Schizontocides or blood schizontocides ("schizontocidal drugs", "suppressive drugs", "suppressants") act on asexual erythrocytic stages of the parasite or suppress them to a subpatent level. They are able to achieve clinical and, for infections with some parasite species (*P. falciparum*), often radical cure. The action may be against any phase of the asexual erythrocytic cycle, not only against schizonts as the name would indicate. When "schizontocide" is used alone it usually refers to a blood schizontocide; if the term were always qualified as "blood schizontocide" or "tissue schizontocide", confusion would be reduced.
FIG. 10. ACTION OF ANTIMALARIAL DRUGS IN RELATION TO THE LIFE CYCLE OF MALARIA PARASITES
(AFTER ALVARADO & BRUCE-CHWATT, 1962)
84. Gametocytocides ("gametocytocidal drugs") destroy sexual forms (gametocytes) of human malaria parasites. Any blood schizontocide destroys the gametocytes of *P. vivax* and probably also of *P. ovale* and *P. malariae*, but not the gametocytes of *P. falciparum*. Consequently drugs that also destroy *P. falciparum* gametocytes could usefully be qualified as falciparum gametocytocides.

85. Sporontocides ("sporontocidal drugs"), when given to a gametocyte carrier, prevent or inhibit the development of oocysts in mosquitos feeding on that carrier. They thus prevent the formation of sporozoites and thereby transmission of the disease. Drugs with such action have also been called antisporogonic drugs. Sporontocides may or may not eliminate gametocytes from the blood stream. Writers in Russian refer in this context to "gametropic" and "gamostatic" effects of the same drugs.

**Uses of antimalarial drugs**

86. Taking into account the practical application of antimalarial drugs, three main categories may be considered: (1) prophylactic (protective) use, (2) therapeutic (curative) use, and (3) use to prevent transmission.

**Prophylactic (protective) use**

87. The word "prophylaxis" is commonly used for any method of protection from disease; chemical prophylaxis should preferably be designated "drug prophylaxis" or "chemoprophylaxis". Prophylaxis implies that the drugs are used before infection or prior to its manifestation, with the aim of preventing either the infection or its clinical or other manifestations. Accordingly, drug prophylaxis may refer to absolute prevention of infection, to causal prophylaxis, or to suppression of parasitaemia and its symptoms ("clinical prophylaxis", "suppression").

Absolute prevention of infection would imply destruction of inoculated sporozoites before they could fix themselves in the tissues. No known drug has this action, hence prophylaxis in the sense of absolute prevention of infection is not yet attainable.

Causal prophylaxis implies complete prevention of erythrocytic infection by destruction of the pre-erythrocytic forms of the parasite directly deriving from sporozoites. Drugs acting as causal prophylactics ("primary tissue schizontocides") must be able to destroy pre-erythrocytic stages before merozoites are first liberated into the blood stream. Thus the main implication of causal prophylaxis is that the infection must be eliminated.
at an early stage and within a short time, not exceeding the normal duration of the prepatent period. If the drug is given beyond that period, or if its effect persists for a much longer time, the prophylactic effect observed may not be causal but clinical ("suppressive"), that is, achieved by destruction of the erythrocytic parasites as soon as they enter the blood stream.

Clinical prophylaxis implies prevention of clinical symptoms by early destruction of erythrocytic parasites. It is said to suppress malaria when it permits the continued existence of exoerythrocytic forms or of some erythrocytic forms which will permit subsequent multiplication of the parasite after discontinuation of the drug. All blood schizontocides are clinical prophylactic drugs or suppressants, since they destroy merozoites entering the blood stream before they can establish schizogony. This results in prevention of erythrocytic infection, or at least in its reduction to a subpatent level, while the drug is being taken, but overt attacks may occur after it is discontinued.

Although, by definition, suppressive treatment aims at preventing the appearance of clinical manifestations, if it is administered to subjects already infected it would also presumably eliminate their parasitaemia. However, if suppressive treatment is given with the sole purpose of eliminating existing parasitaemia, such terms as "drug prophylaxis" and "chemoprophylaxis" should not be applied to it.

**Therapeutic (curative) use**

88. Therapeutic use of drugs refers to treatment of established infections after they have become manifest, whether in the form of clinical symptoms, or parasitaemia, or both. Hence therapeutic uses include treatment of the acute attack, radical treatment, and anti-relapse treatment, any of which may make use of suppressive treatment.

*Treatment of the acute attack* (or of patent parasitaemia) implies chemotherapeutic action against asexual erythrocytic stages of the parasite by means of a suitable blood schizontocide. Treatment of the attack may result either in clinical (temporary) cure, denoting relief of symptoms and elimination of asexual parasitaemia without complete elimination of the infection, or in radical (permanent) cure, indicating complete disappearance of the infecting parasites.

*Radical treatment* (radically curative treatment) refers to treatment adequate to achieve complete elimination of the infection so that relapses cannot occur after the treatment is terminated. Depending on the infecting parasite species, radical cure may require action against erythrocytic parasites, secondary exoerythrocytic forms, or both.
In falciparum infections radical cure is obtained by complete elimination of the asexual erythrocytic parasites and thus can be achieved by means of an appropriate blood schizontocide, supplemented in malaria eradication programmes by a sporontocidal or gametocytocidal drug. In vivax, malariae, and ovale infections, treatment with a blood schizontocide would result only in clinical cure, while radical cure requires usually an additional treatment with a secondary tissue schizontocide to destroy the exoerythrocytic stages responsible for relapses.

*Anti-relapse treatment* is that designed to prevent the occurrence of relapses, particularly long-term relapses, and is generally given shortly before the transmission season or about the time when relapses may normally be expected.

*Suppressive treatment* denotes action against asexual erythrocytic parasites, resulting in suppression of clinical symptoms and parasitaemia. Suppressive treatment, as previously mentioned, may be given for either prophylactic or therapeutic purposes. It may achieve: (1) clinical prophylaxis if given prior to the establishment of infection and/or its manifestation; (2) clinical cure if given after the infection has become manifest; and (3) prevention of relapses if given following the treatment of an acute attack (i.e., during the latent period when the infection is still present but no longer manifest).

In the last-mentioned case, if suppressive treatment is continued until complete depletion of the exoerythrocytic and/or erythrocytic stages of the parasite, no relapse will occur after cessation of drug administration, indicating that a suppressive cure has been obtained. “Suppressive cure” denotes that clinical and parasitological manifestations of the infection have been continuously suppressed by regular drug administration for a long enough time for the infection to die out naturally. In other words, suppressive cure is radical cure brought about by nature, the drug treatment serving the purpose of suppressing the manifestations of the infection during the time of its normal life-span.

**Use of drugs to prevent transmission**

89. Such use of drugs refers specifically to the prevention of infection of mosquitoes and implies either action on gametocytes in the peripheral blood of the human host or interruption of sporogony in the mosquito host. These purposes are achieved by a gametocytocide or by a sporontocide.

**Use of drugs in malaria eradication programmes**

90. In malaria eradication programmes drugs are used with two aims in view: interruption of transmission and complete elimination of the parasite reservoir.
The main types of drug administration in eradication programmes are presumptive treatment of suspected malaria cases, radical treatment of confirmed cases, and mass drug administration, either direct, by distribution of doses, or indirect, in the form of medicated salt. With reference to eradication programmes these terms have definite meanings and precise operational implications.

Presumptive treatment\(^1\) means generally treatment given in a presumptive malaria case (generally a fever case) at the time when a blood sample is taken for examination. It usually consists of a single dose of a schizontocide often with a sporontocide, and its aim is to relieve symptoms possibly due to malaria and to prevent a probable malaria case from being a source of mosquito infection, until such time as radical treatment is given following the confirmation of the malarial infection.

Presumptive treatment is thus a precautionary measure particularly indicated during the consolidation phase when the vector is no longer controlled by insecticides. Its use is limited to selected individuals in whom malaria infection is suspected. A single-dose treatment given to the whole population—for instance, at the time of spraying operations—is a type of mass drug administration and should not be confused with presumptive treatment.

Radical treatment of confirmed malaria cases is the important antimalaria measure during the consolidation and maintenance phases. Its purpose is to eliminate all residual or imported infections and to prevent new spread of the disease in areas no longer protected by insecticide spraying and where transmission could be resumed.

It follows that in malaria eradication programmes, radical treatment must not only be adequate to achieve radical cure and to prevent relapses, but must also (at least when the attack phase is over) render the treated person immediately non-infectious to mosquitoes. The main practical implication is that radical treatment of falciparum infections should be supplemented by a sporontocidal or gametocytocidal drug.

Mass drug administration has its main application during the attack phase of an eradication programme but may sometimes also be useful in the consolidation phase for the elimination of small residual foci of transmission. The drugs and doses to be used, the frequency of treatment and the required thoroughness of coverage depend on local epidemiological conditions and on the particular purpose of the mass drug administration.

During the attack phase, mass drug administration may be used with one of the following purposes:

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\(^1\) The term "presumptive treatment" is not semantically correct but has been adopted for convenience in the absence of a better expression. Naturally, the presumption refers to the disease rather than to its treatment; the latter is provisional or precautionary and is given in a presumptive malaria case while awaiting the result of blood examination.
(1) as an adjuvant measure to insecticide spraying in areas where insecticides alone are fully effective in interrupting transmission;

(2) as a complementary measure to insecticide spraying under conditions where insecticides alone are not able to bring about complete interruption of transmission;

(3) as the sole measure of attack in areas where insecticide spraying is either ineffective or not practicable.

Mass drug administration is used as an adjuvant measure where such administration may be helpful in speeding up the effect of the insecticide and in promoting co-operation of the people. For this purpose it is generally most convenient to combine mass drug administration with spraying operations and to give a single-dose treatment to all those present when house spraying is carried out.

The use of mass drug administration as a complementary measure is indicated in areas where, owing to the behaviour of the particular vector species or to other circumstances, insecticides alone are not capable of achieving complete interruption of transmission. In this case drug administration is necessary to complement an otherwise insufficient effect of the insecticide and must therefore be applied much more frequently and thoroughly than in the first case.

Mass drug administration used as the sole method of attack must be adequate to achieve and to maintain interruption of transmission under local conditions of endemicity. This means that in areas where malaria endemicity is high, mass drug administration as the sole method of attack requires total coverage: every person in the area must receive regularly the prescribed doses of the drug, the doses must be adequate, and administration must be sufficiently frequent and regular to ensure the continuous maintenance of an effective drug concentration in the blood of every individual.

Nomenclature

Chemically related compounds

91. Antimalarial drugs are often classified according to chemical structure, and drugs with the same fundamental unit of structure are said to belong to the same chemical group, chemical series, or chemical class (e.g., 4-aminoquinolines, 8-aminoquinolines, amino-acridines). Drugs which belong to the same chemical group and which may be considered as formally derived from the same parent compound are sometimes called congeners or congeneric drugs (i.e., allied in origin). Drugs which are obtained from a compound of a given fundamental structure by substituting for certain atoms (generally hydrogen atoms) other atoms or radicals are derivatives
of the parent compound. Drugs which have the same or a similar type
and degree of activity may be called equivalents for all practical purposes.
It should be kept in mind that drugs which belong to the same chemical
group (congeners or derivatives) do not necessarily have the same anti-
malarial activity. On the other hand, drugs which are equivalents because
they have a similar type and degree of activity are not necessarily congeners
but may belong to different chemical groups.

Antimalarial drugs belonging to the same chemical group and/or having
similar antimalarial activity are sometimes called simply analogues; this
usage should be avoided, because the term "analogue" alone has no precise
meaning—it is always necessary to specify the kind of analogy. Two drugs
may present important analogies in their chemical structure and may never-
theless have quite different actions; they may even belong to different
chemical groups.

Naming of individual drugs

92. Most antimalarial drugs are known under a variety of names. The
same compound is frequently marketed by several manufacturers, each of
whom coins his own distinctive trade name. In addition to the various
trade names, the same drug may be known in different countries under
different official or non-proprietary names. Classes of drug names should
be distinguished as follows:

1. Chemical names of drugs indicate the exact chemical structure and
thus permit correct identification of the drug. However, chemical names
are generally too long and unwieldy to be acceptable for common use, and
even chemists often abbreviate them to shorter, everyday names.

2. Serial or code numbers are used to designate new compounds which
are still under laboratory or clinical trial; often the number is given a
prefix identifying the laboratory or firm. When a compound is found to
be of definite therapeutic value, a trade name is chosen by the manufacturer,
under which it is marketed. (Sometimes a generic or non-proprietary
name is proposed at the same time.)

3. Trade names or proprietary names (also known as trade-marked or
brand names) are given to drugs by their manufacturers and have the advan-
tage of being, usually, brief and easy to remember. A trade name is regis-
tered, in many countries with the patent office, and is the property of the
firm manufacturing the drug. Trade names thus serve to distinguish be-
tween preparations of a drug produced by different manufacturers. The
use of trade names should be avoided unless products of specific manufac-
turers are intended; when it is necessary to use them they should be written

1 The problem of nomenclature of drugs has been lucidly expounded by Miller (1961).
with an initial capital letter to indicate their proprietary status. In some countries this protected status is further shown by a device such as an encircled R, indicating that the name is a registered trademark.

4. Non-proprietary names (which may be officially approved, pharmacopoeial, free, or generic names) are common designations in which there are no proprietary rights. They are selected in many countries by government or semi-official bodies, with the purpose of providing simple names for general use within the country. However, the fact that different countries have sometimes adopted different non-proprietary names for the same drug has clearly indicated the need for international selection of non-proprietary names. Thus the proprietary product called Atebrin, Atabrine, and Quinacrine by various manufacturers has been given the non-proprietary name quinacrine in the USA and mepacrine in the United Kingdom; Paludrine and Chloroguanide have the non-proprietary names chlorguanide (USA) and proguanil (UK).

International Non-Proprietary Names (I.N.N.)

93. Since 1953, the World Health Organization has been co-ordinating the activities of individual countries in selecting free names for drugs and has been proposing International Non-Proprietary Names for pharmaceutical preparations. These names have been published in the Cumulative List of Proposed International Non-Proprietary Names (World Health Organization, 1962); new lists of these names are issued at regular intervals and published in the WHO Chronicle.

International Non-Proprietary Names have been proposed for the more common antimalarial drugs and should be used in preference to any others, except when it is desired to refer specifically to the product of a particular manufacturer. They include:

- amodiaquine
- amopyroquine
- chloroquine
- chlorproguanil
- hydroxychloroquine
- mepacrine
- pamaquine
- pentaquine
- primaquine
- proguanil
- pyrimethamine

Note that according to the “General principles for guidance in devising International Non-Proprietary Names” (World Health Organization, 1962), the following terminations should be used:

- "ine" for alkaloids and organic bases;
- "quine" for antimalarial substances containing a quinoline group;
- "crine" for antimalarial substances containing an acridine group.

Non-proprietary names (whether I.N.N. or other) should be written with a small initial letter, not a capital.
Expression of dosages

94. Doses of antimalarial drugs should always be stated in fractions of a gram (g) or in milligrams (mg), as should the strength of tablets or other dosage forms. All antimalarial drugs in use are organic bases and form salts with common acids. With the exception of pyrimethamine, antimalarial drugs are always employed in the form of salts because the acid component confers upon the drug certain useful properties, such as ability to crystallize, stability and water-solubility, which are usually absent in the free base. Because only the base component is therapeutically active, and because there are great differences in the percentages of base contained in the various salts, doses of antimalarial drugs should always be expressed in terms of the base.

For antimalarial drugs which are widely used in eradication programmes, most manufacturers now usually indicate only the content of base in their preparations, or, when both the salt and the base content are indicated, give prominence to the latter. A few drugs, however, such as quinine, mepacrine, and proguanil, are commonly prescribed in terms of the salt (i.e., doses stated usually refer to a salt of the compound), even though for quinine, for instance, 1 g of the hydrochloride or of the dihydrochloride contains about 82% of active quinine base, whereas 1 g of the bisulfate represents only 59% of the base.

95. In describing the frequencies of administration of drugs it is best to avoid using terms such as “bi-weekly”, “bi-monthly” and “bi-annually” and instead to specify “twice a week” or “once a fortnight”, “twice a month” or “once in two months”, and so on. “Quarterly” is unambiguous, hence permissible.
V. INSECTICIDES AND SPRAYING EQUIPMENT

Insecticides

96. An insecticide is a product that kills insects; this definition includes compounds lethal to the insect either in its larval stage ("larvicide") or in its adult stage ("immediate imagicide" or "residual imagicide"). The value of an insecticide depends on the interaction of a number of factors related to the insecticidal compound, its formulation, the mode of application, the surface on which it is applied and the insects against which it is used.

97. The residual insecticides used today in most malaria eradication programmes are chlorinated hydrocarbons (DDT, dieldrin, BHC), although promising alternatives have been discovered in the organophosphorus series (malathion, fenthion, dichlorvos) and the carbamates.

DDT is still the most commonly used insecticide in malaria eradication programmes. Dieldrin, in view of its much higher toxicity to mammals and the ease with which it induces resistance, is of limited use but still of value in those programmes in which resistance to DDT has appeared. BHC, which has the additional advantages of both contact and fumigant action and relatively low toxicity to mammals, is used when its relationship to dieldrin with regard to cross-resistance presents no major drawback.

The persistence of these insecticides depends mostly on their volatility. This explains the much longer persistence, on impervious surfaces, of DDT and dieldrin than of the more volatile BHC. Another factor influencing the persistence of an insecticide is its formulation. Formulations used in malaria eradication campaigns are rarely solutions; they are sometimes emulsions or pastes, but most frequently water-dispersible powders. The solvents utilized for solutions are either kerosene, solvent-naphtha or white spirit, which permit the preparation of solutions with concentrations of up to approximately 10%-15%, or aromatic hydrocarbons such as benzene and cyclohexane, permitting concentrations up to 25%-40%, which can be diluted to the required spray concentration.

98. Emulsions are made up of two immiscible liquids, one of which is broken up into globules ("dispersed phase") and scattered in the other

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1 Dieldrin and some related compounds are often designated generically as cycloienes.
liquid ("continuous phase"). The system is stabilized by adding emulsifying agents (surface-active products which prevent the globules from coalescing and thus breaking the emulsion). Breaking of the emulsion results in creaming; in this phenomenon a layer is formed at the top of the emulsion which contains a greater proportion of the dispersed phase than is found in the remainder of the emulsion. Emulsions are prepared from emulsifiable concentrates (10\% -35\%), which are single-phase systems containing the insecticide together with one or more surface-active agents having the property of forming an emulsion on dilution with water. Pastes are special types of emulsion concentrates.

99. In water-dispersible powders the insecticides are diluted with inert carriers; in some stages of their preparation various wetting, suspending, and anti-caking agents are added. Commercially available water-dispersible powders contain up to 75\% of the technical product; the inert carrier may represent 15\% and the dispersing, water-soluble agents 10\% of the formulation. When mixed with water and properly agitated, water-dispersible powders form a suspension, i.e., a mixture of a liquid and an insoluble solid, the latter being present as small particles which are kept in suspension by mechanical agitation. When agitation ceases the solid settles down, more or less quickly according to the size of the particles, their physicochemical properties, and the properties of the dispersing agents. Two closely interdependent factors are of fundamental importance for such formulations: suspensibility and particle size.

Suspensibility is the capacity of the water-dispersible powder for entering into and remaining in suspension; it depends on factors such as the specific gravity of the insecticide, its particle size and that of the inert diluent, the type of diluent used, and the nature and amount of the dispersing agent. In standard formulations of water-dispersible powders the specifications for suspensibility and effectiveness usually require that at least 50\% -70\% of the insecticide content have a particle size below 10-20\mu. For DDT the optimum particle size for anopheline control is 5-20\mu (WHO Specifications for Pesticides, 1961b).

100. The persistence of insecticidal action is also closely related to the surface on which it is applied. In this respect surfaces may be roughly classified as sorptive and non-sorptive with intermediate variations. Non-sorptive or impervious surfaces do not, in practice, interfere with the persistence of the insecticide; on such surfaces the persistence is related to the volatility of the toxicant and the physical characteristics of the insecticide formulation, to mechanical action on the insecticide deposit (removal or coverage by soot, tar, dust, etc.), and to fall-off due to reduced adhesiveness of the crystals. For practical purposes thatched roofs (grass, leaves), wood, bamboo walls, and most concrete surfaces may be considered non-
sorptive. Sorptive or pervious surfaces are those on which the insecticide deposit penetrates gradually below the surface. On such surfaces, of which mud (adobe) is a typical example, the sorption of the insecticide takes place at a speed related to its rate of diffusion in the surface and to its volatility. Thus BHC deposits disappear from a sorptive surface much more quickly than dieldrin and DDT. But the residual action of BHC is prolonged by sorption, which results in a slow release from the sorptive wall surface, whereas dieldrin and DDT are normally inactivated by it.

Sorption is slightly influenced by temperature and is greatly dependent on humidity. In general, any increase in humidity increases the effectiveness of the insecticide deposit. On sorptive surfaces, water-dispersible powder formulations, though they undergo progressive sorption, are preferable to emulsions or solutions, since with the latter the insecticide penetrates below the surface with the liquid. The speed of sorption of the insecticide contained in water-dispersible powders depends on the nature of the insecticide, its particle size, and the nature of the surface. Small particles undergo sorption much more rapidly and are much more rapidly volatilized.

The effectiveness of an insecticide depends on its specific toxicity to the insect, its mode of action, its persistence as conditioned by the relationship between the insecticide and the surface, and the bionomics of the mosquito.

101. Organophosphorus insecticides are a class of compound recently introduced into public health projects. A few of them, following preliminary field investigations, have shown some promise as alternatives to the chlorinated hydrocarbons used in malaria eradication programmes when anopheline resistance to the latter has appeared. Mention should be made of two such compounds, malathion and fenthion (Baytex). Malathion, which can be used with a large margin of safety, is effective on impervious surfaces but is quickly inactivated on sorptive surfaces. Fenthion has been shown to be effective against anopheles for periods up to five months on both pervious and impervious surfaces. However, further toxicological investigations are needed before it can be recommended for malaria eradication programmes. Dichlorvos (DDVP), another organophosphorus compound, is of particular interest since it is a persistent fumigant; the control of the vector is ensured by the action of DDVP vapour constantly released from a dispenser. Various formulations of DDVP and types of dispenser are being investigated.

102. Space-spraying and fumigation consist in the distribution of an insecticide in an open space, indoors or outdoors. It may be achieved by several means, as, for instance, by burning pyrethrum powder, by the use of smoke generators containing chlorinated hydrocarbons, or (more com-
monly today) by the release of insecticidal aerosols. Unlike residual spraying, space-spraying is used for immediate effect.

103. Larvicides are products exerting a lethal effect on the aquatic stage of mosquitoes. Traditional larvicides are petroleum oils and arsenical compounds such as Paris green and calcium arsenite. Today the chlorinated hydrocarbons are applied as larvicidal solutions in oils or as emulsions. They may also be applied on water surfaces or introduced into larval habitats as capsules or as granules, pellets or briquettes; in the latter three formulations a solid carrier (sand, cement, etc.) is impregnated with the insecticide solution and then compacted and made up to the required dimensions of small granules or balls (pellets) or larger briquettes. When these are placed in water the insecticide seeps out slowly.

Spraying equipment

104. Several types of sprayers initially developed for agricultural use have been adapted to the needs of antimalaria house-spraying operations, including the compression sprayer, the stirrup-pump sprayer and the knapsack sprayer. This equipment is designed to produce a uniform insecticide dosage on sprayed surfaces and to be simple, strong and durable so that it can be used by unskilled workmen with elementary maintenance facilities. Figure 11 shows a typical compression sprayer.⁴

A primary requirement is a controllable and uniform nozzle-discharge rate. Variation in the pressure of the liquid at the nozzle and erosion of the nozzle orifice (under the action especially of suspended solids) are responsible for potentially large fluctuations in discharge. A pressure gauge showing the permissible pressure range is sometimes installed to guide the spraymen. With compression sprayers (pre-pressurized) a pressure regulator is sometimes installed in the discharge line which reduces the tank pressure to a predetermined level.

Nozzle spray patterns of different form have been tried, the flat fan being favoured in most programmes because it facilitates application of parallel horizontal or vertical spraying swaths on rectangular surfaces. The size and shape of the pattern produced by a nozzle at any given pressure (including the effective swath width) are shown by measurements made on

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⁴ The terms and definitions of sprayers and sprayer parts included in the present document are those adopted by the Third Report of the WHO Expert Committee on Insecticides (1952) and given in Specifications for Pesticides, 2nd ed. (WHO, 1961b).

⁵ The compression sprayer shown in Fig. 11 is only one among the various models of such sprayers used in malaria eradication programmes. The pressure gauge shown in this figure is an optional feature, and sprayers of this type can be equipped with a constant-pressure valve which delivers a fixed discharge pressure in spite of the fluctuation of pressure in the tank. The terms used for various parts of the compression sprayer are based on Specifications for Pesticides (WHO, 1961b), which gives specifications for other spraying and dusting equipment also.
the dry side of a flat sheet of glass while the spray is impinging on the other side (nozzle spray-pattern test).

**FIG. 11. TYPICAL COMPRESSION SPRAYER**

105. In practice the rate of application of an insecticide is regulated by three controlling factors: its concentration in the liquid carrier, the nozzle discharge rate, and the speed of spraying. Accuracy of concentration is assisted by providing teams with previously weighed and packaged insecticide tank charges and mixing cans marked at the correct liquid tank charge. Accuracy of discharge is maintained by frequent nozzle-discharge tests in the course of the work. Spraying speed is controlled by good training and supervision of spraymen.
VI. OPERATIONAL PROCEDURES IN MALARIA ERADICATION

106. Two concepts of antimalaria campaigns must be clearly distinguished: malaria control and malaria eradication. Malaria control implies the reduction of the disease to a level at which it is no longer an important public health problem, with continuous maintenance of the activity that produced this result. Malaria eradication differs radically from malaria control since its primary aims are the cessation of transmission of malaria, the elimination of the reservoir of infection and the prevention of resumption of transmission, all within a specific time limit. For other differences between the two approaches see the Sixth Report of the WHO Expert Committee on Malaria (1957).

An eradication programme is developed along two main lines of activity: (1) operations supported by the necessary administrative organization and (2) epidemiological assessment of conditions existing before the commencement of the programme, followed by an evaluation of its progress.

107. Because of the size and cost of the undertaking and its importance to the social and economic welfare of a country, a malaria eradication operation is organized on a national scale and undertaken as a national commitment. A malaria eradication board,¹ representing the government departments and international agencies involved in the programme, is often set up to formulate policy and, at times, to guide the programme. A national malaria eradication service is usually in charge of its execution. The structure of the central and field services depends, naturally, on the size of the country and its administrative set-up, but the principle is that of centralized direction and decentralized execution. In countries too large for direct centralized supervision, zones of appropriate size are designated, each with a professional zone chief and with supporting staff and facilities for operations within its limits.

108. Planning for malaria eradication has acquired a terminology based on its strategy and reflecting the need to focus attention at each stage on both immediate and long-range objectives. The undertaking of a full-scale malaria eradication programme presupposes that its technical and

¹ The administrative titles used here are those preferred by WHO and are not necessarily those used in all countries undertaking malaria eradication.
practical feasibility have been assured; failing this, well-planned preliminary steps are required to make up the deficiencies. If there is doubt that the proposed attack method will stop transmission, it must first be tested in a malaria eradication pilot project. If the country's public health service is too weak in personnel, rural organization, and facilities to man a national malaria eradication service and to support the surveillance operation, then a pre-eradication programme is launched to build up these elements to the level essential for the effective implementation of every phase of an eradication programme (WHO, Expert Committee on Malaria, 1959 and 1961).

109. When the basic prerequisites of an eradication programme have been assured and the country has decided to embark on it, a pre-eradication survey is undertaken to gather the necessary data and put together a programme proposal (plan of operations) covering all foreseen operations. A survey and planning board is sometimes charged with this responsibility. The phases of the programme are: the preparatory phase, characterized principally by geographical reconnaissance and training of staff; the attack phase, during which total-coverage house-spraying or other attack methods are carried out; the consolidation phase, during which total-coverage spraying has ceased and surveillance is carried out; and lastly, from the time malaria is eradicated in the country, the maintenance phase (see Fig. 12).

FIG. 12. PHASES OF MALARIA ERADICATION AND EPIDEMIOLOGICAL STATUS OF MALARIA

110. The essential activity during the attack phase of malaria eradication is the use of residual insecticides against the mosquito (house-spraying), but antimalarial drugs may also play an important part in all phases of malaria eradication (WHO, Expert Committee on Malaria, 1961). Despite the widespread applicability of residual insecticides in malaria eradication programmes, there are some situations in which their effectiveness is lowered for various reasons so that the use of additional or alternative measures is indicated. The overall programme to eradicate malaria depends on
perfect coverage but is not necessarily tied to one single attack method. Consequently, wherever the interruption of malaria transmission or the lowering of the parasite reservoir can be more quickly or more effectively achieved by another method of attack, such an action may be planned. The planning must take into account not only the epidemiological characteristics but also the existing facilities for operational activities.

111. Knowledge of the number, location, and accessibility of the houses and field shelters within the malarious area is important for the success of house-spraying and surveillance operations alike. Because of population movements, regional development, and house-building (activities common to areas recently freed of malaria), geographical reconnaissance must be a continuing operation throughout the years of the programme. In addition to the identification and numbering of sprayable houses, this operation provides sample measurements from which the size of the average sprayable surface per house may be determined; this information may be useful in estimating the requirements of insecticide and labour and in checking their utilization.

The progress of a spraying operation is constantly measured by comparing the reported number of localities sprayed and houses sprayed with the respective totals included in the programme. Sprayable houses which for any cause have not been sprayed or have been only partly sprayed when the spraying squad leaves a locality are reported as pending houses. Special measures are in force in eradication programmes to ensure that all pending houses and new constructions are promptly sprayed.

112. The basic field unit for carrying out a spraying operation is the spraying squad, which consists of two to six spraymen and a leader. The squad's predetermined itinerary and area of work are established on the basis of the local sprayman workrate.

The task of the sprayman aiming at total coverage consists of a total, complete, sufficient and regular application of the residual insecticide to all sprayable surfaces of all the dwelling units in the locality concerned. This is not always easy in practice. The word "house" is strictly defined, but the presence of field shelters, known under a variety of local names, must also be taken into account for spraying purposes.

113. The spraying is done at stated intervals. The actual operation of spraying in the locality is the spraying round, sometimes defined in terms of the time taken to complete the work. The spraying of all houses in a given area, repeated at regular intervals, is known as a spraying cycle. The periodicity of insecticide applications is expressed by the two terms "spraying frequency" and "spraying interval". The first refers to the number of insecticide applications per house per year; the second refers to the time elapsing between successive applications.
114. The method of barrier spraying, limited to an appropriate shape and width in relation to topographical features, is sometimes instituted for the protection of a relatively static population. Focal spraying is the treatment of a group of houses within a focus of transmission.

115. Surveillance is an essential part of an eradication programme, as distinct from a malaria control programme. The purpose of surveillance is to discover evidence of the continuation of transmission and to deal with it effectively. The surveillance operations comprise a number of individual functions, of which case detection is the earliest. The two types of case detection, active and passive, differ from each other only in the method used to discover cases, not in the ultimate objective of case-finding. In active detection, case-finding is done by house-to-house visits of surveillance agents employed by the malaria eradication service; in the passive form it is done by malaria detection posts not directly under the control of the service (hospitals, clinics, medical practitioners, and voluntary collaborators). The taking of blood films from persons suspected of having malaria is the responsibility of both types of personnel engaged in surveillance operations. Compulsory notification of all cases of malaria by medical practitioners, hospitals, dispensaries, etc. forms an important element of passive case detection. In some circumstances a mass blood examination of the population may be necessary to supplement normal case-detection methods of assessing the proportion of symptomless parasite carriers in the community.

116. An important activity of the surveillance system is the drug treatment of suspected cases (presumptive treatment) or confirmed cases (radical treatment) of malaria and the epidemiological investigation and follow-up of malaria cases and collateral cases. In some conditions focal spraying is necessary to eliminate or prevent limited transmission, and occasionally a community follow-up is needed in residual or new foci.

117. The concept of total coverage is of importance in all phases of malaria eradication, as it implies the extension and perfection of activities to include every locality and every household (and for case detection, every person) throughout the given period and within a given area. To emphasize some specific aspects of malaria eradication one may refer to total-coverage spraying or total-coverage case detection.

118. During the maintenance phase, after the operation is completed, vigilance is exerted by the public health service against reintroduction of the disease into areas from which it has been eradicated.
VII. PRINCIPLES OF ZOOLOGICAL CLASSIFICATION
AND NOMENCLATURE

119. The starting point of the scientific nomenclatorial system in zoology
is the tenth edition of Linnaeus's *Systema Naturae* of 1758, but no single
code of zoological nomenclature attained international acceptance until
1901, when the Fifth International Congress of Zoology in Berlin approved
a series of rules. The approved text of the *International Rules on Zoological
Nomenclature* was first issued in 1905 in Paris in French with English and
German translations. Modifications of the rules come from the recommenda-
tions of the International Congress of Zoology and from "Opinions and
Declarations" of a permanent body known as the International Commission
on Zoological Nomenclature. This Commission recommends changes in
the code, renders opinions on questions of nomenclature and compiles
a list of official names in zoology. In 1936 an International Trust for Zoologi-
cal Nomenclature was established, and in 1948, at the meeting of the
International Commission on Zoological Nomenclature held in Paris, much
progress was made towards standardization of terminology. Further chan-
ges were made in 1953 at the Fourteenth International Congress of Zoology
in Copenhagen, and eventually a comprehensive revision of the Rules was
prepared for the final approval of the Fifteenth International Congress
of Zoology, held in London in 1958. This revision is now available as the
*International Code of Zoological Nomenclature* (International Commission
on Zoological Nomenclature, 1961), published in one volume with parallel
English and French texts "equivalent in force, meaning and authority".
The rules of the code, followed by all zoologists as a matter of voluntary
acceptance of the opinion of the majority, are not static and will continue
to be modified when necessary by plenary sessions of successive international
zoological congresses.

The International Commission on Zoological Nomenclature has a panel
of commissioners reappointed by each successive International Congress
of Zoology. This Commission exercises plenary powers in the matter of
interpreting the Rules, and requests for decisions are submitted to the Secre-
tary. The decisions are published in *Opinions and Declarations Rendered
by the International Commission on Zoological Nomenclature*.

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1 Much of this chapter is based on Ussing’s (1956) outline of international agreements on systematics,
on Mattingly’s chapter on practical systematics in the Practical Guide for Malariologists in the African
Region of WHO (de Meillon, 1961) and on the introduction to the *International Code of Zoological Nomen-
Some principles of systematics

120. Only a few facets of the complicated and often controversial subject of zoological systematics can be discussed here. Some basic concepts are outlined, however, referring to entomology especially, since the taxonomic problems of entomologists are infinitely greater than those of other specialists because of the larger number of species with which they have to deal.

The basic natural unit of classification of the living world is the species. The term "species" is a collective term for all those individuals capable of breeding with one another but incapable, for genetic reasons, of breeding with individuals of other species. Interbreeding may be prevented or limited if some smaller groups of each population are separated by geographical or climatic barriers. Such isolated groups may gradually develop their own characteristics, which, when sufficiently distinctive, may justify their classification as subspecies. (The subspecies receives formal recognition under the rules of zoological nomenclature.)

121. The constancy of morphological characters in any one species is generally used as a guide for classification within it, but this guide must be used with caution. The term "sibling species" is sometimes used to designate species that are indistinguishable by gross morphological characters but are nevertheless different in their ecological relationships, behaviour and chromosome structure. Their validity as species cannot be questioned if reproductive isolation is accepted as an essential criterion. A species-group is an assemblage of the co-ordinate categories, species and subspecies. The term "species complex" may be used more loosely with regard to some closely related species when their exact specific status is uncertain.

The term "taxon" (pl.: taxa) has been adopted as the designation for any taxonomic unit, such as a family, a genus or a species.

122. The infraspecific categories below the subspecies are the most difficult area of systematics, and the 1958 International Congress of Zoology attempted to agree on a set of rules for nomenclatorial treatment of such groups as races, varieties, forms and aberrations, variously defined by different authors. Some of these differences may be based on genetic factors, while others are due to environmental factors. Often these lower systematic categories grade into one another.

The term "race" is often employed in genetic and other studies to indicate infrasubspecific differentiation not amounting to a definable morphological distinction. The terms "variety" and "form" are often applied to variants of a sporadic kind which do not appear to be organized into stable populations, but they are also used for variations occurring at different points within the area of distribution of a species. Infrasubspecific
groups are excluded from the present Code and its provisions do not apply to them.

123. "Strain" is a term commonly used in malariology with regard to both the parasite and the vector. It generally refers to a population of common stock descending from a single ancestor or derived from a single source and maintained without intermixture from other sources through a number of generations. Such populations may differ physiologically or in their behaviour patterns from other populations of the same species and may be indicated or named according to the source from which they were obtained. In parasitology the term "strain" is commonly used to designate a generation of parasites obtained from a single infection and maintained in a suitable host. The word is also used somewhat loosely for forms of the parasite which behave immunologically as though distinct from other forms of the same species. Homologous strains of malaria parasites produce the same immunological response, while heterologous strains elicit little or no cross-immunity. In parasitology the term "clone" is used for a group of individual organisms produced from a single ancestor by asexual reproduction. With regard to the vector, authors occasionally but unjustifiably refer to a "strain" based on a community of characters of a population found in natural conditions; strictly speaking, strains of mosquitoes must be isolated from a single fertilized female.

Some rules of nomenclature

124. Since their initial adoption the international rules have undergone a number of modifications and additions. The new International Code of Zoological Nomenclature embodies all the changes, supersedes all the previous rules and provides zoologists with a useful set of guiding principles to simplify the task of classification. A few of the rules are summarized here, but for full details the reader is advised to refer to the 1961 edition of the Code.

1. Names become valid only when they appear in a generally recognized publication and when they are based on a proper description and interpretation of recorded observation.

2. The designations of species are binominal, i.e., composed of the name of the genus and that of the species (in Latin or latinized Greek); infraspecific categories (subspecies) may have trinominal nomenclature. The specific name that goes with the generic name must agree with it as a Latin adjective, generally taking into account the gender of the generic noun (e.g., Plasmodium falciparum, but Laverania falcipara). Specific names formed from proper nouns are given in the genitive case (e.g., Anopheles gambiae). The generic
name is given a capital letter and the specific name a small one even if the species name is derived from a proper noun.

3. In formal nomenclature the binominal designation is completed by adding the name of the author of the original description and the date. No comma separates the author's name from the name of the species, but a comma precedes the year. The name of the author and date of description are given in parenthesis only when the generic placing is no longer that of the original author.

4. Each taxonomic group has a typical member. When a new species is described, one of the specimens is chosen as the type ("holotype"). The other specimens seen at the same time are paratypes. A collective type ("syntype") may be designated by the author if no single specimen is good enough to show all the necessary details for identification and hence to serve as a holotype.

5. In principle, if the same name is used for more than one genus or species ("homonyms") or if more than one name has been given to the same genus or species ("synonyms"), the name given and published earlier is accepted and the other is changed or suppressed. Generally speaking, once a name has been published the author has no property rights to it and it becomes common property, subject to amendments, corrections and substitutions.

6. Changes in the spelling of scientific names—a constant source of confusion—are now comprehensively codified. The new Code deals also with many other points, such as criteria of publication, validity of names, formation and emendation of names, authorship, and homonymy. Appendices to the Code cover the transliteration of words and names, recommendations on the formation of names, and rules for zoologists publishing new names.

7. One of the fundamental principles of the international rules is the application of the law of priority. According to this, precedence is given to the name first applied to a given genus or species. In order to establish priority it is necessary to know the year when a particular name was made public. If two equally valid names are published in the same year, priority extends to the month or even day of publication.

8. The international rules are not applied mechanically, and there is a recent tendency to a more liberal conception of their function. Thus it is now held that names given by an author but not intended to be used for a specific taxonomic purpose need not come into obligatory use. There is also a trend to accord more attention to the "principle of conservation", according to which names unused in the zoological literature for over fifty years are considered "forgotten names" (nomina oblitera) and may not be revived without permission of the Commission.
9. The use of abbreviations for generic names is not subject to any rules; this is a matter of convenience which has no significance so far as the nomenclature is concerned. In papers and other publications it is usual to give the full name of the genus the first time a species of that genus is mentioned. Subsequent mentions of that species or of other species belonging to the same genus need not be preceded by the full name of the genus but only by its initial.\(^1\) If, however, the use of the initial could cause confusion (e.g., the initial \(P\). for \(Plasmodium\) and for \(Polychromophilus\) in the same publication, or \(A\). for \(Anopheles\) and for \(Aedes\)), then either an arbitrary abbreviation of the generic name (e.g., \(P\.\) or \(P\.\) or \(A\.\)) should be used to avoid ambiguity or the full generic name should be given.\(^2\)

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\(^1\) Thus, for example, \(Plasmodium\) \(malarium\) or \(Anopheles\) \(gambicoides\) would be given in full at first mention, but later in the same paper it would be permissible to write \(P\.\), \(P\.\), \(A\.\), \(A\.\), \(A\.\), and so on.

\(^2\) A similar approach should be followed for trinomial designations. The first time they are mentioned they should be spelled out in full: \(Anopheles\) (or \(A\.\), as explained above) \(mimicry\) \(minimus\), \(A\.\) \(minimus\) \(fluviatilis\). Subsequently only the subspecific name must be repeated (\(A\.\) \(minimus\), \(A\.\) \(fluviatilis\)). Here, too, no nomenclatural significance is attached to such arbitrary abbreviations, the important point being to avoid confusion. Thus if in the same paragraph we speak of various subspecies of \(A\.\) \(maculipennis\) and \(A\.\) \(minimus\), it would be permissible to write \(A\.\) \(mac\.\) \(maculipennis\) and \(A\.\) \(min\.\) \(fluviatilis\).
GLOSSARY

Parenthetic numbers following some definitions indicate paragraphs of the preceding chapters in which additional information is given. Italics are used in cross-references to indicate the word under which a term is entered in the Glossary.

Abbott's formula. Formula used in applied entomology for correction of insect mortality figures in observations where any significant mortality (over 5%) occurs among controls. The corrected proportion is \((x-y)/x\), where \(x\) is the proportion surviving among the controls and \(y\) that surviving among the test insects. See also check mortality.

absorption. Process of attraction of one substance into the mass of another. The basic physical forces involved are those of osmosis and diffusion. See also sorption.

adsorption. Adhesion which takes place at the surface of a solid or a liquid in contact with another medium (solid, liquid or gas) resulting in an accumulation or increased concentration of molecules from that medium in the immediate vicinity of the surface. See also sorption.

aerosol. Suspension of solid or liquid particles in air or gas, ranging in size from 0.1 to 50\(\mu\). An insecticidal liquefied-gas aerosol is one produced by the extremely rapid volatilization of a liquefied or compressed gas, serving as a propellant for a non-volatile oil solution of an insecticide. As the liquefied gas volatilizes, it propels the oil solution in the form of an aerosol of very fine droplets. The size of the droplets varies with the product but must be less than 50\(\mu\) in diameter. The gases used are generally dichlorodifluoromethane (Freon-12) or trichlorofluoromethane (Freon-11), which do not involve a toxic hazard to warm-blooded animals.

aestivation. State of survival of mosquitoes by means of behavioural and physiological changes during periods of high temperature and drought.

age, epidemiologically dangerous. Minimum age at which a female mosquito can transmit sporozoites in the prevailing climatic conditions. (65)

age, physiological. Number of gonotrophic cycles undergone by a female mosquito. (65)

age composition. Frequency distribution of ages in a population or a specified fraction of it.

age-grading. Classification of female mosquitoes according to their physiological age (number of gonotrophic cycles) or simply as nulliparous or parous. (65)

age groups. Sections of a community classified by age. (38)
analogue. In chemical terminology, one of a group of substances having similar properties or showing similarity or agreement with regard to certain characteristic features. The term should be qualified according to the type of analogy. (91)

Anopheles. Genus (or subgenus) of mosquitoes of the subfamily Anophelinae.

Anophelinae. Subfamily of the Culicidae which includes the genus Anopheles.

anophelism. Presence of anophelines in a locality, irrespective of the presence of malaria.

anthropophilic. Showing a preference for feeding on man even when non-human hosts are available. A relative term requiring qualification so as to indicate the extent of this preference.

attack. 1. Period of acute (overt) illness consisting of a single paroxysm or of several separate paroxysms. The first attack following the incubation period is called the "primary attack." (20) 2. In malaria eradication terminology, the phase during which antimalarial measures applicable on a large scale and aiming at the interruption of transmission are applied on a total-coverage basis in an operational area. This phase is sometimes called the period of total-coverage spraying. (110)

autochthonous. Term applied to malaria contracted locally. (35)

back-cross. The mating, in the laboratory, of insects from one colony or strain with the progeny of a cross-mating between that strain and another.

barrier spraying. See under barrier spraying.

batch. Eggs deposited by a single female mosquito at any one oviposition.

benign tertian. Colloquial name for vivax malaria.

BHC. Abbreviation and common name of benzene hexachloride, a chlorinated hydrocarbon insecticide comprising essentially a mixture of isomers of 1,2,3,4,5,6-hexachlorocyclohexane in the form of whitish to light-brown granules, flakes, or powder. The gamma-isomer is the most active constituent. The grades of BHC commercially available are distinguished according to their gamma-isomer content as follows:

- technical BHC: 12% - 16%
- refined BHC: 16.1% - 98.9%
- lindane: 99% - 100%

bioassay. In applied entomology, the experimental testing of the biological effectiveness of an insecticide by deliberately exposing insects to it. Each series of bioassay tests requires specification of the test mosquito species, their age, sex, and physiological condition, the concentration of the insecticide per unit of surface or of air volume, the age of the deposit, the type of material on which the insecticide has been applied, the time of exposure of the insects, and the temperature and humidity at the time of testing. (73)

bioassay mortality. Mean mortality of a sample of test mosquitoes employed in a uniform series of bioassay tests.
GLOSSARY

biting-capture. Collection of mosquitoes caught in the act of feeding on a human or animal host.

biting cycle. Regular variations in the amount of blood-feeding activity exhibited by populations of mosquito species during each 24-hour day-and-night period.

black spores. Dark banana-shaped or round bodies occasionally observed on the midgut wall of the mosquito in association with oocytes and thought to be the result of the secretion of chitin around tracheoles or foreign bodies.

blackwater fever. Fever, often severe or fatal, characterized by acute intravascular haemolysis with haemoglobinuria; believed to be due to repeated infection with falciparum malaria and often precipitated by the taking of quinine. Sometimes called "haemoglobinuric fever".

blood meal. Ingestion by a female mosquito of the blood obtained from a vertebrate host; also the ingested blood.

breeding place. Site where eggs, larvae, or pupae of mosquitoes are found; larval habitat. (66)

bromeliad malaria. See under bromeliad malaria.

brood. Parasites belonging to the same generation and at about the same stage of development.

caking. Phenomenon which sometimes occurs in water-dispersible powder concentrates of insecticides during storage under conditions of relatively high humidity and temperature and/or under pressure, causing formation of solid lumps which may adversely affect the suspensibility of the powder. An anticaking agent is sometimes added to water-dispersible powder.

capture station. Site selected for periodic sampling of the mosquito population of a locality. It may be any place where adult mosquitoes rest. Such stations are often used for checking fluctuations in mosquito densities.

carrier. 1. Person harbouring malaria parasites with or without clinical evidence of infection. In malaria eradication terminology the carrier state is considered as a type of malaria case. 2. Finely ground inert mineral added to the technical product in the formulation of insecticide dusts and water-dispersible powders to facilitate their use. The most important inert carriers, or diluents, are the silicates of aluminium and magnesium (e.g., talcs, pyrophyllites, bentonites, clays) and the diatomaceous earths.

case. An occurrence or instance of infection or disease. The word is so vague that the type of case should always be specified, as, for instance, a malaria case or a fever case.

case, collateral. In malaria eradication terminology, a case occurring in the immediate vicinity of a malaria case which has been the subject of an epidemiological investigation (may be specified as collateral fever case, collateral suspected case, etc.). This is the equivalent of the epidemiological term "contact" used in many infectious diseases, which would be inaccurate in malaria where infection does not spread by contact.
case, suspected. In malaria eradication terminology, a case other than a fever case believed to be one of malaria infection. It may be convenient in some programmes to introduce a subclassification of this category according to the reliability of the source of information regarding the suspected case.

case detection. In malaria eradication terminology, one of the activities of surveillance operations concerned with the continuous search for malaria cases in a community. The purpose of case detection is to identify malaria-infected persons, treat them and furnish the necessary data for assessment of the malaria situation. Case detection is a screening process, using as its indicator either the symptom of fever or specific epidemiological attributes. It differs from the malarriometric survey in the following respects: (a) the screening covers the entire population at risk without any age discrimination; (b) the criteria for selection are of a clinical or an epidemiological nature; and (c) the process is continuous, while malarriometric surveys are based on sporadic random-sample surveys of the younger age groups. Active case detection is the process of case-finding by visiting, at regular intervals, all houses of a malarious area and taking blood specimens of any inhabitants who have, or have recently had, fever. The house-to-house visits are made by the staff of the malaria eradication service or by other designated official health personnel. Passive case detection is the finding of malaria cases through notification by medical or other collaborating personnel to whom fever cases and other suspected cases are reported. Malaria detection posts are the main sources of notification, but other medical and paramedical personnel may contribute to passive case-detection operations and in some instances constitute the only source. In order to qualify for inclusion in the general organization of passive case detection, such notification must be accompanied by a blood slide. See also malaria detection post. (54, 115)

case follow-up. Periodic re-examination with or without treatment. In malaria eradication terminology the term implies that a blood film is examined and treatment given if appropriate. It may involve, for example, anti-relapse therapy at the beginning of the transmission season. Case follow-up is a part of surveillance.

check mortality. Mortality of a sample of mosquitoes which, in tests of an insecticide, are kept as controls, being submitted to the same conditions as the test mosquitoes except for the toxicant itself. Also known as "control mortality", "comparison mortality". See also Abbott’s formula. (76)

chemoprophylaxis. Protection from or prevention of disease by chemotherapeutic means. (87)

chromatin. Nuclear material of the malaria parasite or of other cells having a characteristic staining reaction.

clonal. Generations of individual organisms descended by asexual reproduction from a single individual (ancestor).

colony. Self-contained population of a mosquito species maintained in a laboratory through one or more generations. (62)
community follow-up. In malaria eradication terminology, the intensification of normal surveillance operations, including periodic examination of a large part of the population, in remaining or new malaria foci.

completed locality. In malaria eradication terminology, a sprayed locality in which every possible effort has been made to spray all sprayable houses, including those previously classed as pending.

concentration, median lethal. That concentration of an insecticide (utilized to impregnate the absorbent papers used in tests) sufficient to kill 50% of the mosquitoes of a sample exposed to the insecticide during a specified period. Abbreviated LC50. (76)

congener. In chemical terminology, one of a group allied in origin, i.e., all belonging to the same chemical group and derived from the same parent compound; thus the 4-aminquinolines are congeners with, or congeners of, one another. The fact that two compounds belong to the same chemical group does not necessarily imply that they have the same type or degree of activity.

consolidation. In malaria eradication terminology, the phase that follows the attack phase; it is characterized by active, intense and complete surveillance with the object of eliminating any remaining infections and proving the eradication of malaria. It ends when the criteria for eradication have been met.

constant-pressure valve. Synonym of pressure regulator.

control mortality. Synonym of check mortality.

creaming. Phenomenon occurring when the dispersed phase of an emulsion rises to the top to form a more concentrated layer (e.g., cream layer in milk).

crenation. Formation of a notched or wavy edge at one or both ends of an oval red blood cell infected with Plasmodium ovale.

crescent. Common term for the gametocytes of P. falciparum and P. reichenowi.

cross. In genetics, the mating; in the laboratory, of members of two colonies or strains of the same species, or the product of such a mating, which may be fully fertile, incompletely fertile, or sterile. (The term "cross" is sometimes incorrectly applied to hybrid offspring of a mating between distinct species.)

cross-resistance, insecticide. Resistance to an insecticide developed in a mosquito population by selection pressure from another insecticide belonging to the same group (e.g., the DDT-methoxychlor group or the dieldrin-BHC group). Not to be confused with double resistance to an insecticide (see under resistance, 2).

cryptozoite. Exoerythrocytic stage of malaria parasites arising directly from sporozoites in the tissues of the vertebrate host. Term limited at present to avian malaria parasites.

cure, clinical. Relief of symptoms of a malaria attack (e.g., by chemotherapeutic action against asexual erythrocytic parasites) without complete elimination of the infection.
cure, radical. Complete elimination of the malaria parasite from the body so that relapses cannot occur. Radical cure may be brought about by natural means in the absence of specific medication (natural or spontaneous cure), by radical treatment, or by suppressive cure. (88)

cure, suppressive. Complete elimination of the parasite from the body by means of continuous suppressive treatment. (88)

cytomere. Island of cytoplasm in a growing schizont; usually uninucleated first and later multinucleated, giving rise finally to merozoites. (11)

cytoplasm. Cell substance other than nuclear material and special organelles.

DDT. Abbreviation and common name of dichlorodiphenyl trichloroethane, a chlorinated hydrocarbon insecticide comprising essentially 1,1,1-trichloro-2,2-di-(p-chlorophenyl)ethane in the form of white or cream-coloured granules, flakes or powder. Technical DDT should contain a minimum of 70% by weight of p,p'-isomer having a minimum melting point of IO4°C.

DDVP. Abbreviation for dimethyl dichlorovinyl phosphate (dichlorvos).

density, anopheline. Number of female anophelines in relation to the number of specified shelters or hosts (e.g., per room, per trap, or per person) or to a given time period (e.g., overnight or per hour), specifying method of collection.

density, average infective. Average number of female anophelines of a species that are found with sporozoites in the salivary glands per standard collecting unit (room or person) per unit of time. (72)

density, parasite. See under parasite density.

depot preparation. Synonym of repository drug.

deviation, animal. Increase in the proportion of mosquitoes feeding on non-human hosts, with consequent reduction in the proportion feeding on man.

diapause. Condition of suspended animation or temporary arrest of growth in the mosquito.

diazinon. An organophosphorus residual insecticide. Technical diazinon should contain at least 85% by weight of 0,0-diethyl 0-(2-isopropyl-4-methyl-pyrimidinyl-6)phosphorothioate.

dichlorvos. Organophosphorus insecticide (O,O-dimethyl 2,2-dichlorovinyl phosphate, abbreviated DDVP) which kills mosquitoes by fumigant action. (101)

dieldrin. Chlorinated hydrocarbon insecticide, comprising essentially 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-endo-1,4-exo-5,8-dimethano napthalene (HEOD). Technical dieldrin should contain at least 76.5% by weight of HEOD.

dispersion. Scattering of a locally concentrated mosquito population. Mosquito dispersion may be active or passive. See also migratory flight; pre-hibernation flight. (67)

distribution. Geographical, seasonal, ecological or topographical range of an organism.
GLOSSARY

**dose.** 1. Amount of a drug to be given for the treatment of a particular condition; usually graded in accordance with the age and weight of the recipient. 2. Average amount of insecticide discharged per unit of surface sprayed, expressed in grams of technical product (gamma-isomer, for BHC) per square metre (nozzle dosage). Since some proportion of spray does not reach or does not remain on the target, this dosage is always higher than the actual amount deposited.

**dose, adult.** Amount of a drug to be given to an adult person (all persons over the age of 14 years may be considered adults).

**dose, daily.** Amount of a drug to be taken every 24 hours.

**dose, discriminating.** Amount of an insecticide (usually expressed as the concentration per standard period of exposure) which in a sample of mosquitoes containing resistant individuals distinguishes between phenotypes and determines their respective proportions. Where the genetic factor for resistance is either dominant or recessive, only one discriminating dose operates. Where it is semi-dominant, two such doses may operate: a lower discriminating dose killing susceptibles only and an upper discriminating dose killing both susceptibles and heterozygous (but not homozygous) resistant individuals.

**dose, loading.** Initial dose of a drug, higher than that regularly used, given with the objective of rapidly providing an effective drug concentration.

**dose, maximum tolerated.** Largest dose that can be taken without harm within a stated period of time.

**dose, median lethal.** Amount of a toxicant sufficient to kill half the individuals of the sample tested. In applied entomology, the amount of insecticide, usually applied by topical application, found sufficient to kill 50% of the mosquitoes treated. Abbreviated LD_{50}. (76)

**dose, minimum effective.** Smallest dose found to produce a stated effect.

**dose, single.** Quantity of a drug prescribed to be taken on a single occasion and intended to produce an effect without further medication.

**drug.** Substance or mixture of substances intended to be used in the prevention, mitigation or treatment of disease or of an abnormal physical state or the symptoms thereof in human beings or animals.

**drug, causal prophylactic.** Synonym of primary tissue schizontocide.

**drug, repository.** Sparingly soluble drug or drug preparation which, on being injected intramuscularly or subcutaneously, forms a local depot from which the active principle is gradually released into the circulation. Also known as "depot preparation ".

**drug association.** Simultaneous administration of two or more drugs, either in separate or in compound preparations.
**drug failure.** Absence or insufficiency of drug action after administration of a normally effective dose. It is important to discriminate between such causes of drug failure as deficient absorption, unusual rate of degradation or excretion of the drug, and resistance of the parasite.

**drug interference.** Inhibition or diminution of the effect of one drug by another.

**ecdysis.** Casting of the successive larval skins. (61)

**eclosion.** Emergence of the imago from the pupal case; hatching of the larva from the egg. (61)

**EE.** Abbreviation for *exoerythrocytic*.

**effectiveness.** As applied to an insecticide, its ability to kill mosquitoes or other insects against which it is directed. To be distinguished from *persistence*.

**emergence.** Synonym of *eclosion* but used mainly with regard to the adult insect coming out of the pupal case. (61)

**emulsifiable concentrate.** Monophase liquid system containing an insecticide together with one or more surface-active agents having the property of forming an emulsion on dilution with water. (98)

**emulsion.** Two-phase system, having a reasonable degree of stability, in which a liquid is dispersed in droplets ("dispersed phase") within a second liquid ("continuous phase"). (98)

**endemic.** Term applied to malaria when there is a constant measurable incidence both of cases and of natural transmission in an area over a succession of years. For the degrees of malaria endemicity (endemic prevalence) based on the spleen rate of children and adults see also hypendemic, mesoendemic, hyperendemic, and holoendemic *malaria*. (36)

**endophagy.** Tendency of mosquitoes to feed indoors. (68)

**endophily.** Tendency of mosquitoes to rest indoors, whether by day or by night. (68)

**epidemic.** Term applied to malaria when the incidence of cases (other than seasonal rises) in an area rises rapidly and markedly above its usual level or when the infection occurs in an area where it was not present previously. (36)

**epidemiological investigation.** In the broad sense, the study of the environmental, personal and other factors that determine the incidence of disease. In malaria eradication it is a part of surveillance operations and is concerned with ascertaining the origin and means of infection in any malaria cases discovered; determining, by localized mass blood examinations (epidemiological survey), the existence and nature of any malaria foci in the neighbourhood; and seeking, by entomological and other means whenever necessary, to establish whether transmission is taking place and, if it is, its source.

**erythrocytic.** Developing within red blood cells; applied to stages of the malaria parasite.

**excito-repellency.** Property in an insecticide of stimulating irritability in insects.
exflagellation. Extrusion and liberation of microgametes (flagella) by male gametocytes.

exoerythrocytic. Developing in tissues outside the red blood cells; applied to stages of the malaria parasite in the vertebrate host. Abbreviated EE. (12)

exophagy. Tendency of mosquitoes to feed outdoors.

exophily. Tendency of mosquitoes to rest outdoors, whether by day or by night.

extender effect. Delayed degradation or excretion of a drug (or of its active metabolite) brought about by concurrent administration of another substance.

fat-body. Tissue which partially fills the body cavity of an insect and plays a many-sided role in its metabolism; in particular it serves as a place for the accumulation of reserve substances in overwintering female mosquitoes.

fenthion (Baytex). Organophosphorus insecticide containing 95%–98% 0,0-dimethyl-O-(3-methyl-4-methyli thiophenyl)phosphorothioate in the form of a brown liquid smelling slightly of garlic. (101)

fever. Increase of body temperature. It may be classified as (a) continuous, (b) remittent (characterized by decreases but without a return to normal temperature), or (c) intermittent (interrupted by periods of normal temperature). (20)

fever case. In malaria eradication terminology, an occurrence of fever, which is classified as (a) actual (current)—i.e., existing at the time of examination or during the previous four days; or (b) recent—i.e., occurring since the preceding visit of a surveillance agent or in the four weeks before examination exclusive of the four immediately preceding days.

field shelter. Non-movable living quarters temporarily housing agricultural or other workers who normally reside elsewhere. Field shelters are called by a variety of names in different countries: “farm huts”, “crop huts”, “rice kitchens”, etc.

fimbriation. Synonym of crenation.

flight, migratory. Directional flight of a group of mosquitoes, not subject to the ordinary laws of dispersion.

flight, pre-hibernation. Dispersion or migration of mosquitoes occurring before and in relation to hibernation, often to greater-than-normal distances.

flight range, effective. Distance from a breeding place that the females of a given species of mosquito travel in numbers sufficient to maintain endemic malaria or to cause an epidemic.

focus, malaria. See under malaria focus.

formula, parasite. See under parasite formula.

fumigant. Any product, such as an insecticide, which exerts a toxic effect through its vapour.

gamete. Mature sexual form, male or female. In malaria parasites the female gametes (macrogametes) and male gametes (microgametes) normally develop in the mosquito. (14)
gametocyte. Parent cell of a gamete. In malaria parasites, the female gamocytes (macrogamocytes) and male gamocytes (microgamocytes) develop in the red blood cell. Very young gamocytes cannot usually be distinguished from trophozoites. (14)

gametocytocide. Drug which destroys the sexual forms of malaria parasites. (84)

gametocytogenesis. Formation of gamocytes.

geographical reconnaissance. In malaria eradication terminology, the operation which provides the basis for the choice of field centres and depots, for detailed schedules and itineraries of spraying and surveillance personnel, for the final deployment of transport, and for numerical control of the completeness of work accomplished. It includes collection of information on the number, type, location and means of access of all houses and field shelters, as well as on communications, health units, vehicle-repair facilities, population movements and other relevant factors.

gonotrophic concordance. Trophic activity in the female mosquito (e.g., blood ingestion) with gonadal development.

gonotrophic cycle. One complete round of ovarian development in the mosquito, often stated in reference to the period of time required for its completion. (63)

gonotrophic dissociation. Trophic activity in the female mosquito (e.g., blood ingestion) without gonadal development. Also known as “gonotrophic discordance”.

haematin. Ferrihaemiacid, found in malaria pigment. (16)

haemoglobinuric fever. Synonym of blackwater fever.

hand-capture. Method of collecting individual mosquitoes resting on a surface by the use of a simple test-tube or a suction device and, generally, a source of light.

hatching. Emergence of the larva from the egg.

hibernation. State of survival, by means of behavioural or physiological changes, during periods of cold. Animals becoming temporarily and occasionally active during such periods are said to be in a state of partial hibernation. (69)

host. Living animal or plant harbouring or affording subsistence to a parasite; also a cell in which a parasite lodges (“host cell”).

host, definitive. Host in which sexual reproduction of the malaria parasite occurs. The mosquito is often described as being the definitive host of the malaria parasite, but it is preferable to use the more specific term “invertebrate host”.

host, intermediate. Host in which only asexual forms of the malaria parasite develop. Man is often described as being the intermediate host of human malaria parasites, but it is preferable to use the more specific term “vertebrate host”.

host preference. Preference of mosquito for a particular type of host, e.g., human or animal; to be distinguished from mere readiness to feed on a particular type of host when no other is available.
house. In malaria eradication terminology, any structure other than a tent or mobile shelter which serves as a dwelling. For purposes of measuring the progress of spraying operations, houses are continuously reported as sprayed or as pending and the numbers of these compared with the number originally designated for spraying ("sprayable houses"). See also house-numbering.

house-numbering. Designation by serial numbers of houses within specified geographic limits which are subject to visits by personnel of the malaria eradication service for the purpose of house-spraying, surveillance, inspections, etc. From an operational standpoint a house to be numbered as a unit consists of a structure or a group of contiguous structures, including the living rooms and dependencies, which is occupied continuously or periodically by a single family and consequently accessible for spraying or inspection upon a single request. (111)

house-spraying. In malaria eradication terminology, application of a residual insecticide in liquid form to specified (mostly interior) surfaces of buildings. House-spraying is the primary method of attack in most malaria eradication programmes. The spraying is (a) total, when all dwellings designated to be sprayed receive the insecticide; (b) complete, when all the surfaces to be sprayed are thoroughly treated; (c) sufficient, when the prescribed dosage is applied; and (d) regular, when the spraying cycles needed to interrupt transmission are maintained. (111)

house-to-house visiting. In malaria eradication terminology, the primary process of active case detection in which a surveillance agent or other member of the malaria eradication staff (or of the general health services) visits every household in a locality (village, town, etc.) in order to search for fever cases, take a blood slide in each such case and administer presumptive treatment.

imagicide. Insecticide used for destroying insects in the adult stage. (79)

imago. Completely developed stage of the insect, often termed "adult".

immunity. All those natural processes which prevent infection, reinfection or superinfection, or which assist in destroying parasites or in limiting their multiplication, or which reduce the clinical effects of infection. Immunity may be natural and independent of previous infection—for example, man is naturally immune to avian malaria; or it may be acquired, either passively or actively. There is some evidence of human passive immunity to malaria by maternal transfer during the first months of life in malarious areas ("congenital immunity" or "neonatal immunity"); the latter term is preferred by immunologists. Active malarial immunity is acquired as a result of previous infection. (28, 29)

immunity, concomitant. Synonym of premunition.

immunity, infection. Synonym of premunition.

immunity, residual. Immunity consequent on infection and persisting after its termination. (29)
incidence. Number of cases of disease occurring during a given time period in relation to the unit of population in which they occur (a dynamic measurement). Not to be confused with prevalence. (33)

incidence, annual parasite. Number (per thousand of a population) of microscopically confirmed malaria cases detected during one year. The epidemiological value of the annual parasite incidence depends entirely on whether the population to which this figure relates was covered by an adequate system of case detection. (55, 56)

incubation interval. Period elapsing between the occurrence of infective gametocytes in a human subject and their appearance in an infective form in a secondary case deriving from the first case. The term includes one parasite cycle in the mosquito and one or several in man; it is also called "infection cycle".

incubation period. 1. Time elapsing between the initial malarial infection in man and the first clinical manifestations. When the time is extended to many times its normal length it is known as a protracted incubation period; this may occur in *P. vivax* infections in the autumn in some temperate climates, where the infected person may show no clinical signs until the following spring. 2. Time needed for the completion of sporogony in the mosquito up to the infecting stage (known as the extrinsic incubation period).

index.* 1. Figure indicating the proportion which one happening or number bears to another; a measurement of one type of value used to indicate another. (33) 2. Token or sign indicating (but not measuring) a quantity or value. 3. Loosely, a rate.

index, anthropophilic. Synonym of human blood index.

index, host preference. Figure indicating the proportion of freshly fed anophelines giving a positive precipitin reaction for any specified host in the particular conditions in which capture has been made.

index, human blood. Figure indicating the proportion of freshly fed anophelines found to contain human blood.

index, infestation. Figure indicating the proportion of houses or places found to contain a specified insect. The use of this term with regard to the degree of malaria parasitaemia is not recommended.

index, maxillary. Mean number of teeth per maxilla of female mosquitoes.

index, parasite-density. Mean parasite count among those persons found positive in a sample of the population; calculated either as the geometric mean or as the weighted average of the individual parasite counts divided into arbitrary classes. (50)

indicator district. Selected part or selected number of villages of the malarious area of a country in which the results of periodic surveys or case detection, or both, are used for assessment of the effectiveness of the eradication measures applied in the attack phase of malaria eradication. Such an area must repre-

* Terms entered here as indices may be called "rates" by some authors and vice versa; both entries should be consulted for such terms.
sent the overall condition of the entire malarious area of the country or of the particular epidemiological zone from which it is chosen. The selection of an indicator district (also called "index area") and the initial survey must take place in the preparatory phase, at the latest.

**infected anopheles.** Female anopheles with oocysts of malaria parasites on the midgut wall (with or without sporozoites in the salivary glands). To be distinguished from infective anopheles.

**infection.** Entrance, establishment or maintenance in a host of a parasite, generally involving its multiplication; also the resulting condition in the host.

**infection, mixed.** Malaria infection with more than one species of Plasmodium.

**infection immunity.** Synonym of premunition.

**infection interval.** Period elapsing from the time an individual is infected until he himself becomes infectious to others. In malaria the infection interval is the period from the inoculation of a human being with sporozoites until the appearance of gametocytes potentially infective to mosquitoes. To be distinguished from incubation interval and incubation period.

**infectious.** Capable of transmitting infection; term commonly applied to the human host.

**infective.** Capable of transmitting infection; term commonly applied to the parasite (gametocytes, sporozoites, etc.) or infecting agent.

**infective anopheles.** Female anopheles with sporozoites in the salivary glands (with or without oocysts in the midgut). To be distinguished from infected anopheles.

**infestation.** Relationship of ectoparasites to the host or of vermin or pests such as mosquitoes to an environment in which they are numerous. The term has been loosely used in malaria literature in the following senses: (a) "acute infestation": early state of infection among children who have high parasitaemia and acute illness; (b) "immune infestation": the stage of infection following "acute infestation", characterized by low parasite density and the development of tolerance. Such uses of "infestation" to refer to malarial parasitaemia are not recommended.

**insecticide.** Product that kills insects either in their immature stages ("ovicide", "larvicide") or in their adult stage ("immediate imagicide" or "residual imagicide").

**insecticide, contact.** Insecticide which exerts a toxic action when its particles come into contact with the insect's cuticle.

**insecticide, fumigant.** Insecticide which acts through the release of vapour from a volatile substance.

**insecticide, residual.** Insecticide which, when suitably applied on a surface, maintains for a considerable time its insecticidal activity by either contact or fumigant action. (79, 97)

**insecticide avoidance.** Development, in a strain of insects, of the ability to avoid contact with an insecticide. This term is preferred as more truly descriptive
than "behaviouristic resistance", the term used by the WHO Expert Committee on Insecticides (1957 and 1960) mainly because it had been generally accepted. (78)

**Instar.** 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. (61)

**Intensity.** Vague term often loosely applied in malariology with reference to the degree of severity of symptoms, the level of parasite density, morbidity or parasite rates, vector densities, etc. Should preferably be replaced by a precise term indicating the relevant measurement.

**Interruption of transmission.** Cessation of transference of malaria by mosquitoes from one person to another. In malaria eradication terminology, refers exclusively to the cessation of transference secured by antimalarial measures at any stage before eradication is achieved.

**Irritability.** Readiness of mosquitoes to take flight in response to external stimuli.

**Irritant.** Insecticidal or other substance which disturbs resting mosquitoes and stimulates them to fly. (78)

**Itinerary.** In malaria eradication terminology, the listed work sequence of a spraying squad, a surveillance agent or other mobile operational unit, showing localities and target dates, usually with an accompanying map.

**James's stippling.** Fine, evenly distributed granulations brought out by suitable staining in red cells infected with *P. ovale*.

**Key, taxonomic.** List of distinguishing morphological characters so arranged as to facilitate identification of species. The commonest form is the dichotomous key, in which the characters are displayed as pairs of alternatives ("couplets").

**Knockdown.** Rapid immobilization of an insect by an insecticide without necessarily causing early death.

**Larvicide.** Substance used to kill aquatic larvae by ingestion, contact, respiratory blockage, etc. Modern larvicides are applied in the form of oils or emulsions, or as small pellets or granules of inert material such as bentonite, impregnated with insecticide, which is released gradually when they are placed in water. (103)

**Latent period.** Stage during which malarial infection in the vertebrate is not evidenced clinically by any symptoms of disease; occasionally used for the condition in which few or no parasites can be detected by microscopic examination. There is normally a latent period preceding the primary attack ("incubation latency") and a period or periods of latency between the relapses following the primary attack, when the erythrocytic forms have disappeared from the blood but infection persists.

**Laverania.** Generic (or subgeneric) name applied by some authors to *P. falciparum* and *P. reichenowi*. 
LC<sub>50</sub>. Abbreviation for median lethal concentration.

LD<sub>50</sub>. Abbreviation for median lethal dose.

leaching. Solution in water and subsequent unequal distribution or loss ("leaching out") of a water-soluble drug mixed with crude, hygroscopic common salt that has absorbed water.

lindane. Gamma-isomer of BHC.

macrogamete. Female gamete.

macrogametocyte. Female gametocyte.

maintenance. In malaria eradication terminology, period which begins when the criteria of malaria eradication have been met in an operational area and which will continue until world-wide eradication has been achieved. During this period vigilance is exercised by the public health services to prevent the spread of malaria imported from across the borders of the area concerned.

malaria, benign tertian. Synonym for vivax malaria.

malaria, bromellad. Malaria transmitted by species of Anopheles that breed in certain bromeliaceous plants in South and Central America.

malaria, cerebral. Form of pernicious malaria associated with cerebral symptoms and due to infection with Plasmodium falciparum.

malaria, chronic. Colloquial term for the state of ill-health associated with prolonged and repeated malaria infection. Its use is not recommended.

malaria, congenital. Malaria infection directly transmitted from mother to child; such infection is relatively rare and usually takes place in utero through the placenta (prenatal or true congenital malaria), but it is believed that it may also occur at delivery. The term "hereditary malaria" is not recommended.

malaria, falciparum. Malaria infection caused by Plasmodium falciparum.

malaria, holoendemic. Degree of malaria endemicity in an area characterized by a spleen rate in children (2-9 years) constantly over 75% but a low adult spleen rate.* Another characteristic of holoendemicity is the high tolerance of the adult population. (36)

malaria, hyperendemic. Degree of malaria endemicity in an area characterized by a spleen rate in children (2-9 years) constantly over 50% and also a high adult spleen rate.* In areas of hyperendemicity the parasite rates are usually high not only in children but also in adults. (36)

malaria, hypoendemic. Degree of malaria endemicity in an area with a spleen rate in children (2-9 years) of 10% or less.* (36)

malaria, imported. See under imported malaria case.

malaria, indigenous. See under indigenous malaria case.

* Based on classification of Malaria Conference in Equatorial Africa (World Health Organization, 1951).
malaria, induced. Malaria infection properly attributable to the effect of a blood transfusion or other form of parenteral inoculation, but not to normal transmission by the mosquito. The course of the infection may be different from that observed in the normal case. Induced malaria may occur accidentally or may be produced deliberately for therapeutic or experimental purposes.

malaria, introduced. See under introduced malaria case.

malaria, malariae. Malaria infection caused by Plasmodium malariae. The term “quartan malaria” is preferable.

malaria, man-made. Malaria resulting from human activities, often constructional or agricultural, which have provided a local environment suitable for the proliferation of vector mosquitoes.

malaria, mesoendemic. Degree of malaria endemicity in an area with a spleen rate in children (2-9 years) between 11% and 50%.* (36)

malaria, ovale. Malaria infection caused by Plasmodium ovale.

malaria, pernicious. Malaria infection with severe symptoms, usually due to Plasmodium falciparum.

malaria, quartan. Colloquial name for malaria infection caused by Plasmodium malariae. This term is preferred to “malariae malaria”.

malaria, refractory. Term used by some authors to describe persistence or slow and gradual reduction of the amount of malaria despite total-covering spraying.

malaria, relapsing. See under relapsing malaria case.

malaria, responsive. Term used by some authors to describe malaria that is rapidly reduced in amount by total-covering spraying soon after the beginning of the attack phase.

malaria, simian. Malaria naturally occurring in apes and monkeys. Some simian species of Plasmodium have been experimentally transmitted to man.

malaria, simple tertian. Synonym for vivax malaria.

malaria, stable. Epidemiological type characterized by steady prevalence which does not show great change during one transmission season, or from one season to another, except as the result of extreme changes in the environmental factors affecting transmission. Epidemics are unlikely; the affected population often shows a high degree of immunity. This condition is usually linked with the presence of vectors exhibiting pronounced man-biting habits and longevity. (36)

malaria, subtertian. Synonym of falciparum malaria.

malaria, tertian. Synonym of vivax malaria.

malaria, tropical. Synonym of falciparum malaria. Also known under the obsolete name of “aestivo-autumnal malaria”.

malaria, unstable. Epidemiological type characterized by very variable prevalence, typically showing great changes from one part of the transmission season

* Based on classification of Malaria Conference in Equatorial Africa (World Health Organization, 1951).
to another and from one year to another. Epidemics are common and often attributable to minor causes; the population usually shows little immunity. This condition is usually linked with the presence of vectors which do not exhibit very pronounced man-biting habits or great longevity. (36)

**malaria, vivax.** Malaria infection caused by *Plasmodium vivax*.

**malaria case.** In malaria eradication terminology, occurrence of malaria infection in a person in whom, regardless of the presence or absence of clinical symptoms, the presence of malaria parasites in the blood has been confirmed by microscopic examination. During surveillance, every malaria case detected is classified, according to the origin of the infection, as indigenous or as imported, introduced, relapsing or induced. (35, 54, 57)

**malaria case, imported.** Case in which the infection was acquired outside the area in which it is found, implying that its origin can be traced to a known malarious area. (35)

**malaria case, indigenous.** Case that is natural to an area or country, i.e., not introduced. The term is applied to cases whose origin from local transmission cannot be disproved. In malaria eradication terminology relapsing cases are not classified as indigenous. (35)

**malaria case, induced.** See under induced *malaria*.

**malaria case, introduced.** In malaria eradication terminology, a case in which it can be proved that the infection is the first step (direct secondary) of local transmission subsequent to a proved imported case.

**malaria case, relapsing.** In malaria eradication terminology, the classification used for a case shown by the history of the subject to be a probable relapse if careful epidemiological investigation shows that the infection was contracted before the interruption of transmission was claimed in the locality and if there are no epidemiologically related malaria cases in the neighbourhood. (35)

**malaria control.** Operations aimed at reducing the prevalence of malaria to a level at which it is not a major public health problem. (106)

**malaria detection post.** In malaria eradication terminology, a unit or person, forming part of the apparatus of passive case detection, by whom blood slides are taken in all fever cases (not only in suspected malaria cases) and to whom the service responsible for malaria eradication gives regular supervision (as well as making arrangements for the preparation, transport and examination of blood slides and checking the results). Unsupervised persons or institutions from whom notifications are received, with or without supporting blood slides, are not regarded as detection posts, even though their activities may be of value in the case-detection system. Most frequently the designation applies to a rural health centre or dispensary or to a voluntary collaborator, but it may also apply to, for example, a hospital or a medical practitioner. (115)

**malaria eradication.** "The ending of the transmission of malaria and the elimination of the reservoir of infective cases in a campaign limited in time and carried to such a degree of perfection that, when it comes to an end, there is no resumption of transmission" (WHO Expert Committee on Malaria, 1957,
page 4). This objective does not necessarily include the eradication of the vector mosquitoes. The concept of malaria eradication must be distinguished from malaria control, which aims at reducing the disease to a low level and is of indefinite duration. (106)

**malaria eradication board.** Term used in some countries for a high-level co-ordinating body set up to formulate policy and in some cases to exercise technical and administrative direction of the country’s malaria eradication programme.

**malaria eradication pilot project.** Operation intended to provide evidence as to whether certain single or combined antimalaria measures will, if properly applied, bring about the interruption of transmission, and if so, within what period. Within this framework it is possible in a special type of field project to study the most economical, effective and speedy technical means of eradicating malaria.

**malaria eradication programme.** Operation aimed at achieving malaria eradication. The phases of a malaria eradication programme are: preparatory, attack, consolidation, and maintenance. (106, 109)

**malaria focus.** In malaria eradication terminology, a defined and circumscribed locality situated in a currently or formerly malarious area and containing the continuous or intermittent epidemiological factors necessary for malaria transmission: a human community, at least one source of infection, a vector population and the appropriate environmental conditions. The use of the term to mean a "focus of infection", i.e., one or more persons having parasites in their blood capable of infecting mosquitoes, is not recommended. It should be noted that during the attack and consolidation phases, when malaria transmission has already been interrupted in the area around the focus by the appropriate operations, transmission can take place in the focus itself but not in its contiguous environment. Malaria foci may be classified as residual or new. (58)

**malaria parasite.** Colloquial term for any of the protozoan organisms causing malaria infections, including the infection of animals by parasites of the order Haemosporidia.

**malaria pigment.** Compound of haematin (ferrihaemiacid) and protein occurring in the cytoplasm of erythrocytic forms of malaria parasites through the decomposition of haemoglobin by the parasite. The pigment is detectable in the organs and tissues following destruction of the parasites, and in ookinetes and oocysts. The terms "melanin" and "haemozoin" are not recommended.

**malaria survey.** Investigation carried out in an area with the object of determining the main features of malaria under the existing circumstances and thus ascertaining the most suitable antimalaria measures.

**malarriogenic.** Conducive to transmission of malaria.

**malarriometric survey.** Investigation conducted in selected age-group samples of a population in randomly selected localities in order to assess the degree of malarial endemicity. Such a survey is concerned with the measurement of the prevalence of malaria as indicated by spleen and/or parasite rates in
random samples of the population. It is used in pre-eradication operations and
in the preparatory and early attack phases of malaria eradication programmes.
Later, when the amount of malaria has been considerably reduced, the indices
furnished by malarialmetric surveys are no longer sensitive enough to measure
further progress. (32, 53, 54)

**malarotherapy.** Treatment of certain diseases, notably neurosyphilis, by deliber-
ately infecting the patient with malaria. See also induced *malaria.*

**malarious area.** Area in which transmission of malaria is taking place, or in
which it has been present during the preceding four years; or, in malaria
eradication terminology, an area where transmission has apparently or actually
ceased but where final eradication has not been proved.

**malathion.** An organophosphorus insecticide. Technical malathion should
contain O,O-dimethyl S-[1,2-di-(ethoxycarbonyl)ethyl] phosphorodithioate in
a proportion by weight of not less than 95%. (101)

**malignant tertian.** Obsolescent term for falciparum *malaria.*

**mass blood examination.** Examination of the blood of all persons in a unit of the
population, which may be repeated at certain intervals. Blood spec' mens are
commonly obtained during house-to-house visits. Unlike other case-detection
methods, mass blood examinations are used to discover all persons harbour-
ing malaria parasites, even those who have no clinical symptoms; they thus
supplement the routine methods in special problem areas and are useful in
demonstrating the proportion of asymptomatic carriers present in the com-
munity examined. They form a part of case-detection activities and must be
distinguished from malarialometric surveys, which are carried out on a sampling
basis in selected groups. Mass blood examinations have sometimes been called
"mass blood surveys", but this term should be avoided in the interests of
clarity.

**mass drug administration.** Distribution of a specified drug to every member of a
population. The frequency of distribution depends on the purpose, the nature
and dosage of the drug, and local conditions. Although the intention is that
the drug shall reach every member of the population, the practical difficulties
of ensuring this may be considerable. (90)

**maturation.** Final stage in the formation of the macrogamete, by which it is
prepared for union with the microgamete.

**Maurer’s spots.** Irregular granulations (spots, clefts or stippling) brought out by
special staining in erythrocytes parasitized by *Plasmodium falciparum.*

**medicated salt distribution.** Distribution of common salt containing an anti-
malarial drug in such a proportion that every user will obtain with his regular
food a daily amount of the drug sufficient to eliminate malaria parasites from
the blood stream. Also known as "Pinotti’s method."

**meiosis.** Process involving reduction division in a diploid nucleus. In malaria
parasites it was originally thought to take place during the maturation of the
macrogamete by the extrusion of polar bodies; today meiosis is believed to take
place in the first division of the nucleus of the zygote (in the oocyst).
merozoite. Product of segmentation of a tissue schizont, or of an erythrocytic schizont before entering a new host cell. Merozoites are found either separated from or contained in the original schizont.

metacryptozoite. Exoerythrocytic stage of the malaria parasite arising from the cryptozoite and occurring prior to the invasion of erythrocytes. Term limited at present to avian malaria parasites. (12)

metaxenos, metoxenos. Term applied to parasite that requires two or more host species for completion of its life cycle.

microclimate. Conditions of temperature, humidity, and other factors in the immediate environment of an organism, as opposed to the general environment.

microgamete. Mature male gamete.

microgametocyte. Male gametocyte.

mist. Suspension in air of droplets generated by condensation of a fluid from the gaseous to the liquid state or by the breaking up of a liquid by atomization. Mists may be produced by high-pressure pumps, atomizers, or high-speed mechanical rotors; their droplets range in size from 50 to 100 $\mu$.

multiparas. Term describing female mosquito that has oviposited more than once.

notification, compulsory. Reporting of detected cases of malaria by all medical units and medical practitioners, to either the health department or the malaria eradication service, as laid down by law or regulation. Usually this is restricted to clinical or microscopically confirmed cases and does not include suspected cases. Compulsory notification in a country supplements passive case detection or, under certain conditions, replaces it.

nozzle liquid distribution. Liquid discharge rate from a nozzle upon each element of a sprayed surface. For the flat-spray nozzles used in house-spraying, the nozzle liquid distribution is expressed as a curve whose ordinates show the variations in dosage at different points between the edges of a swath. Graphs obtained for a given type of nozzle are used to determine its suitability for house-spraying at different nozzle pressures and to indicate the amount of overlap of successive swaths needed to produce uniformity of dosage. A routine liquid-distribution test of new and used nozzles is carried out with appropriate laboratory apparatus to determine their suitability. In the field the liquid distribution of a nozzle is often tested by observing the uniformity in speed of drying of different parts of a swath sprayed on a smooth, porous wall. Not to be confused with nozzle spray pattern.

nozzle output. Synonym of nozzle discharge rate.

nozzle spray pattern. Instantaneous pattern produced by liquid discharged from a nozzle against a flat surface perpendicular to the centre line of the jet. Patterns may be open cones, solid cones, or flat fans. Flat-spray nozzles are commonly used for house-spraying. A nozzle-spray-pattern test is used to determine the pattern of the impinging liquid by observing it from the dry side of a sprayed pane of glass. Not to be confused with nozzle liquid distribution.

nulliparous. Term describing female mosquito that has never oviposited.
oocyst. Fertilized female cell (zygote) after encystment, developing in malaria parasites from the ookinete.

ookinete. Motile vermicle stage of the malaria parasite, following fertilization of the macrogamete and preceding oocyst formation.

organophosphorus insecticides. Group of synthetic insecticidal compounds containing one or more phosphorus atoms chemically bonded either directly or indirectly through nitrogen, oxygen or sulfur to the carbon atoms of organic radicals. They include diazinon, fenthion, dichlorvos and malathion and have as their common effect the inhibition of a variety of esterases. (101)

ovarian stages. In the mosquito, the progressive changes in the ovary and ovarioles during oogenesis, representing degrees of development of the oocytes and variously classified by different authors. (64)

ovariole. Tapered follicular tube in which oogenesis takes place. The ovary of the mosquito is composed of numerous ovarioles. In parous mosquitoes the thin membranous wall of the follicular tube usually shows a dilatation at the position of a former follicle. The number of such dilatations indicates the number of completed gonotrophic cycles and thus the physiological age of the mosquito. (64)

overwintering. Survival through the winter, irrespective of the means by which this is achieved.

oviposition. Act of laying eggs.

ovulation. Passage of an oocyte from its follicle to the point where it is fertilized just before the egg is laid.

ovum. Cell produced in the female reproductive organ which, after maturation and fertilization, is capable of developing into an organism.

parasitaemia. Condition in which malaria parasites are present in the blood. If this condition in the human subject is not accompanied by pyrexia or other symptoms of malaria except for a possible enlargement of the spleen, it is known as asymptomatic parasitaemia, and the person exhibiting the condition is known as a symptomless parasite carrier. Asymptomatic parasitaemia may be primary (occurring before primary-attack symptoms) or secondary. (24)

parasite clearance time. Time elapsing from the first drug administration to the first occasion on which no parasites can be demonstrated in the blood.

parasite count. Number of parasites per cubic millimetre of blood on a given slide. (48)

parasite density. Collective degree of parasitaemia in a population, calculated by the use of either the geometric mean or the weighted average of the individual parasite counts. (50)

parasite formula. Statement of the relative prevalence of each species of human malaria parasite found in a group of positive slides, i.e., the percentage of each species in the total number of infections. When slides show a mixed infection, each species is counted separately. To be distinguished from species infection rate. (51)
Paris green. Double salt of arsenite and acetate of copper, used as a larvicide.

parous. Term describing female mosquitoes that have oviposited at least once.

paroxysm. Cyclic manifestation of acute illness in malaria characterized by a rise in temperature with accompanying symptoms; usually caused by invasion of the blood by a brood of erythrocytic parasites. (21)

patent period. Stage during which malarial infection in the vertebrate is evidenced by the presence of parasites in the blood. A subpatent period is sometimes distinguished during which parasites are believed to be present in the blood in very small numbers but are not detectable by normal microscopic examination.

pending houses. In malaria eradication terminology, any sprayable houses reported as partially or completely unsprayed at any time before the end of the current spraying operations, often classified for operational convenience as "refused" or "closed".

periodicity. Recurrence at regular intervals of symptoms in malaria, characterized clinically by paroxysms and resulting from the invasion of the blood by new generations of parasites. Periodicity may be quotidian, tertian, quartan or double-quartan according to the intervals between paroxysms. (21)

peripheral spraying. Synonym of barrier spraying.

persistence. As applied to an insecticide, its enduring presence after its application. In house-spraying, generally expressed as the proportion of the insecticide deposit that remains, at any given time after application, either on or below the treated surface in an active or potentially active form. To be distinguished from effectiveness. (97, 100)

phænozoïte. Exerythrocytic stage of malaria parasite in the vertebrate host arising in blood-induced infections or appearing later than the infection of erythrocytes. Term limited at present to avian malaria parasites. (12)

phase, extrinsic. That part of the life cycle of Plasmodium occurring in the vector.

phase, intrinsic. That part of the life cycle of Plasmodium occurring in the vertebrate host.

Pinotti's method. Synonym of medicated salt distribution.

pit shelter. Pit dug in the ground and used for collection of mosquitoes resting in it, in order to obtain information on outdoor resting density. It is used for estimating density changes or changes in resting habits.

Plasmodium. Generic name of the parasites of human malaria. (2, 8, 9)

pre-eradication programme. Preliminary operation undertaken in a country whose general administrative and health services have not yet reached a level which would enable it to undertake a malaria eradication programme. (108)

pre-eradication survey. Operation aimed at the collection of accurate data on the malaria situation, preliminary to drafting a complete plan of operations for a malaria eradication programme. The undertaking of the survey presupposes the existence of evidence that transmission can be interrupted by the use of
methods commonly employed in malaria eradication and the existence of basic operational facilities. The pre-eradication-survey period ends when the plan of operations has been prepared. (109)

**pre-erythrocytic.** Existing before the infection of erythrocytes; applied to exoerythrocytic stages of *Plasmodium* developing directly from the sporozoites. See also exoerythrocytic schizogony.

**premunition.** State of resistance, in a host harbouring a parasite, to superinfection by a parasite of the same species; this state is dependent on the continued survival of parasites in the body and disappears after their elimination. May be complete or partial. (29)

**preparatory phase.** In malaria eradication terminology, time devoted to preparation for the attack operations. It ends when the epidemiological and geographical reconnaissance in the operational area are completed, the central and peripheral stations and essential services established, the staff recruited and trained, and the logistic and reporting systems organized. (109)

**prepatent period.** Early stage of malarial infection in the vertebrate, before the invasion of erythrocytes is microscopically detectable.

**pressure regulator.** Mechanism in a sprayer which maintains a pre-set pressure at an outlet despite variations in pressure at the inlet. Also called "constant-pressure valve".

**prevalence.** Number of cases of disease or infection existing at any given time in relation to the unit of population in which they occur (a static measure). Malaria prevalence can be established on a single malariometric survey, whereas malaria incidence, which is a dynamic measure, requires a method of repetitive or continuous search. (33)

**prophylaxis.** Any method of protection from or prevention of disease; when applied to chemotherapy it is commonly designated "drug prophylaxis" or "chemoprophylaxis". (87)

**prophylaxis, causal.** Complete prevention of erythrocytic infection by the administration of drugs that destroy either the sporozoites or the primary tissue forms of the malaria parasite. (87)

**prophylaxis, clinical.** Synonym of suppressive treatment.

**pupa.** Stage between the larva and the imago in the development of the mosquito, during which it is aquatic and active but does not feed. When the larva undergoes metamorphosis into a pupa ("pupation") the fourth and last larval skin is cast.

**pyrogenic level.** Estimated least quantum of parasites causing pyrexia; varies greatly with the strain and species of parasite and the tolerance of the individual.

**quartan.** Recurring every third day (every 72 hours). Recurrence on two successive days, with one-day free intervals, is known as double-quartan periodicity. See also quartan malaria.
quotidian. Recurring daily.

race. Genetically distinct mating group within a species. To be distinguished from a subspecies, which is geographically isolated as well as being genetically distinct.

rate. Proportion which one happening or number bears to another. In malaria eradication terminology, proportion of a group in which a specified characteristic has been demonstrated by examination either of the whole group or of an adequate sample. (33)

rate, annual blood examination. In malaria eradication terminology, number of blood slides examined during a year in relation to the population covered by case detection. The annual blood examination rate refers to the number of blood slides and not to the number of persons examined (the latter figure may be smaller, as some persons are examined more than once during the year). It is not a fever rate, since it also includes slides collected in non-febrile cases during mass blood examinations and in epidemiological investigation. (56)

rate, anopheline infection. Percentage of female anophelines of a given species found, by dissection within 24 hours of capture, to contain malaria parasites either as sporozoites in the salivary glands or as oocysts on the midgut wall. (72)

rate, biting. Average number of mosquito bites received by a host in unit time, specified according to host and mosquito species.

rate, gametocyte. Percentage of individuals in a given population whose blood contains sexual forms of malaria parasites.

rate, inoculation. Number of individuals per unit of population receiving infective inocula in a given unit of time. This rate may be estimated from (a) study of the frequency of infection in infants (parasitologically estimated rate) or (b) the relative infective density of the vectors (entomologically estimated rate). (37)

rate, malaria morbidity. Number of recorded clinical cases of malaria per unit of population over a certain period. The malaria morbidity rate is too imprecise to be of value in malaria eradication. (33)

rate, malaria mortality. Number of recorded deaths from malaria per unit of population over a certain period. (34)

rate, nozzle discharge. Amount of liquid passing under pressure through the nozzle of a sprayer in a unit time. It is dependent on the pressure, the viscosity of the liquid, and the characteristics of the nozzle. In the standard nozzle-discharge-rate test, the result, expressed in milliliters per minute at a specified pressure, is obtained by measuring the amount of water passing in unit time through a nozzle which has been previously cleaned.

rate, oocyst. Percentage of female anophelines caught in nature and found, on dissection within 24 hours of capture, to contain oocysts in the midgut. (72)

* Terms entered here as rates may be called "indices" by some authors and vice versa; both entries should be consulted for such terms.
rate, parasite. Percentage of persons in a defined age group showing, on a given date, microscopically detectable parasites in the peripheral blood. The parasite rate should always be defined in terms of the age group examined. (47)

rate, reproduction. Estimated number of malarial infections potentially distributed by the average non-immune individual in a community where neither mosquitoes nor persons were previously infected. When conditions are static the rate can be estimated if the sporozoite rate, the probability of mosquito survival and the time of extrinsic development of the parasite are known.

rate, slide positivity. Percentage of slides found positive, usually computed for a stated period of case-detection activities.

rate, species infection. Percentage of individuals found infected with a given species of malaria parasite in a sample of population (e.g., P. falciparum infection rate). To be distinguished from parasite formula. (51)

rate, spleen. Percentage of persons (usually children) showing palpable enlargement of the spleen at a given time. If the spleen rate is investigated in adults, it should be specified as "adult spleen rate". (39)

rate, sporozoite. Percentage of female anopholes caught in nature and found, on dissection within 24 hours of capture, to contain sporozoites in the salivary glands. (72)

ratio, nulliparous. Proportion of a population of female mosquitoes which has not laid eggs.

ratio, parous. Proportion of a population of female mosquitoes which has undergone at least one gonotrophic cycle.

recovery, spontaneous. Clinical or radical cure brought about by nature, in the absence of specific medication.

recrudesence. Renewed manifestation of infection (short-term relapse) believed due to survival of erythrocytic forms. Not to be confused with recurrence. (20)

recurrence. Renewed manifestation of infection (long-term relapse) believed due to reinfection of erythrocytes from exoerythrocytic forms. Not to be confused with recrudesence. (20)

reinfection. Establishment of a fresh infection after a previous similar infection has died out or has been eliminated by treatment.

relapse. Renewed manifestation (of clinical symptoms and/or parasitaemia) of malarial infection separated from previous manifestations of the same infection by an interval greater than those due to the normal periodicity of the paroxysms. Relapses are sometimes classified as recrudescences and recurrences; they can be either clinical or parasitic, the latter being evidenced only by the reappearance or increase in number of the parasites in the blood. The qualifications "short-term" and "long-term" may be used to designate relapses following the primary attack after intervals of less than two or more than six months, respectively. (20)

repellent. Any substance which produces a negative response in mosquitoes, causing them to avoid a close approach such as alighting on the skin of the animal host or entering a room sprayed with the substance.
repository drug. See under repository drug.

residual deposit. Deposit of a residual insecticide, i.e., one remaining on sprayed surfaces after the solvent, emulsifier or carrying fluid has evaporated.

resistance. 1. Ability of a parasite strain to multiply or to survive in the presence of concentrations of a drug that normally destroy parasites of the same species or prevent their multiplication. Such resistance may be relative (yielding to increased doses of the drug tolerated by the host) or complete (withstanding maximum doses tolerated by the host). 2. Ability in a population of insects to tolerate doses of an insecticide which would prove lethal to the majority of individuals in a normal population of the same species; developed as a result of selection pressure by the insecticide. Simultaneous resistance to one or more insecticides of two different groups is known as double insecticide resistance (not to be confused with insecticide cross-resistance). (75-77)

resistance, behavioural. Synonym of insecticide avoidance.

resistance, physiological. In mosquitoes, all forms of resistance to insecticides other than so-called “behaviouristic resistance”. (75-77)

ring form. Annular form of young trophozoites of malaria parasites in blood cells.

Romanovsky stain. Mixture of eosin, methylene blue and methylene azure which stains differentially the various elements of malaria parasites.

rosette. Colloquial name for some types of mature schizont.

schizogony. Asexual process in the malaria parasite involving the production of erythrocytic or exerythrocytic schizons. The stages of schizogony occurring in cells other than erythrocytes in the vertebrate host (“exerythrocytic schizogony”) are divided into (a) primary EE forms (“pre-erythrocytic stages”, “primary tissue forms”), in which EE forms are present before the erythrocytes are normally invaded; and (b) secondary EE forms (“exerythrocytic forms sensu stricto”, “para-erythrocytic stages”, “secondary tissue forms”), in which EE forms are present after the erythrocytes are normally invaded. (12)

schizont. Intracellular asexual form of the malaria parasite, developing either in tissue or in blood cells. The nuclei of schizonts show evidence of schizogenic division. The schizonts are qualified as mature when the nuclei and the cytoplasm are fully divided so that the merozoites have taken shape; erythrocytic schizonts are then called “segmenters” or (colloquially) “rosettes”. (12, 13)

schizontocide. Drug which destroys the asexual forms of malaria parasites. Schizontocides are distinguished as blood schizontocides and tissue schizontocides. When “schizontocide” is used alone, it usually refers to a blood schizontocide, i.e., one which acts on the erythrocytic asexual parasites. Tissue schizontocides are those drugs which destroy the exerythrocytic stages of the parasite. If they act on the primary exerythrocytic forms they are referred to as primary tissue schizontocides (“causal prophylactic drugs”); if on the secondary forms, as secondary tissue schizontocides. (83, 88)

Schiffner’s dots. Fine, evenly distributed granulations brought out by suitable staining in red cells infected with P. vivax and P. ovale. The granulations seen in Plasmodium ovale infections are better known as James’s stippling.
segmentation. Schizogonic division of malaria parasites leading to the formation of merozoites.

segmenter. Mature erythrocytic schizont.

selection pressure. In applied entomology, any selective effect of an insecticide favouring survival of those individual insects which carry a particular hereditary factor or factors, while those which do not carry these factors are killed. (76)

smoke, insecticidal. Insecticide particles produced and distributed in the air by smoke generators. The particles in insecticidal smokes of pyrethrum, rotenone and arsenicals range between 0.3 and 2 μ in diameter.

smoke generator. Apparatus used to produce insecticidal smoke, as from slow-burning pellets, canisters, fumigant candles, etc., in which the insecticide is mixed with some inflammable material which is ignited.

sorption. Term covering the phenomena of adsorption and absorption which occur when an insecticide deposit rests on a pervious surface; the action takes place partly from the vapour phase but mostly by direct diffusion from the crystals over the surface, with further diffusion inside the underlying layers. It generally results in progressive inactivation of the insecticide deposit. (100)

source of infection. Person harbouring malaria parasites infectious to a vector mosquito, who may have clinical symptoms of malaria or may be a symptomless parasite carrier. Any person with parasitaemia should be considered a potential source of infection.

space-spraying. Spraying of a given space (not a surface) in or out of doors. (102)

species. Group of organisms capable of exchanging genetic material with one another and incapable, by reason of their genetic constitution, of exchanging such material with any other group of organisms. The limits of species are indicated by the comparative study of morphological and other characters. (120)

species complex. Group of closely related organisms, the exact specific status of which is uncertain, although they resemble some well-recognized type species.

species-group. An assemblage of co-ordinate categories, viz., species and subspecies.

species eradication. Complete elimination from a territory of one or more species of malaria vectors.

spleen, average. Weighted average spleen size determined in all subjects of a specified age group in an examined sample of the population, including those whose spleens are not palpably enlarged. (This index is rarely used.)

spleen, average enlarged. Weighted average spleen size of those subjects with a palpably enlarged spleen in a specified age group of the sample of population examined. This index is obtained by multiplying the number of individuals in each arbitrary classification of enlarged spleen by the class number, adding the products, and dividing the total by the number of individuals whose spleens are palpable. (43)
spleen measurement. Determination of spleen sizes in a group of persons, usually children 2-9 years of age, as a basis for classification, usually into arbitrary classes numbered from 0 to 5. From the results the average-enlarged-spleen value is calculated. (42)

sporadic. Term applied to malaria when autochthonous cases are too few and scattered to cause any appreciable effect on the community. These cases are often due to relapses of a previous infection; for purposes of epidemiological classification by origin of infection, the term “relapsing” is then preferred. (35)

sporogony. Process of development occurring in the mosquito which follows sexual union of gametes and ends with the formation of sporozoites.

sporontocidé. Drug which, when given to the malaria-infected vertebrate host, prevents or interrupts the development of the parasite in mosquitoes feeding on that host. Also known as “antisporogenic drug”. (85)

sporozoite. Final stage of sporogony of Plasmodium in the mosquito; the infective form of the malaria parasite occurring either in a mature oocyst before its rupture or in the salivary glands of the mosquito.

sporulation. Strictly, production of spores by multiple cell fission; incorrectly used for schizogony.

sprayable. In malaria eradication terminology, designated (or of a type designated) for spraying.

sprayable surface. Parts of a sprayable house and its furnishings which are designated for spraying. The mean estimated area of the sprayable surfaces expressed in square metres (or square feet) per house or per inhabitant is termed the “average sprayable surface”.

spray-capture. Collection of mosquitoes which are knocked down by a quick-acting insecticidal spray within a closed space.

sprayed houses. In malaria eradication terminology, those structures designated for spraying in which all sprayable surfaces are reported as completely sprayed by the end of the current spraying operations. See also house-spraying. (111)

sprayed locality. In malaria eradication terminology, a locality in which all sprayable structures have been sprayed during the current spraying operations except for pending houses. (111)

sprayer. Apparatus used for applying liquid insecticides, herbicides and fungicides, in solution, emulsion or suspension, to sprayable surfaces (also called “spray pump”). The three types usually used in malaria eradication programmes are the compression sprayer, the stirrup-pump sprayer and (rarely) the knapsack sprayer. (104)

sprayer, bucket-pump. Synonym of stirrup-pump sprayer.

sprayer, compression. Pneumatic, pre-pressurized sprayer (also known as “pneumatic sprayer”). The pressure is normally furnished by a hand-operated pump incorporated in the apparatus, but it may be supplied from an inde-
pendent source. The tank is usually circular in shape, with a working capacity of approximately 7½-15 litres (2-4 US gal). The sprayer is fitted with one or two straps for convenience in carrying. (104)

sprayer, knapsack. Sprayer designed to be carried on the back by two straps passing over the shoulders of the operator. A continuous discharge is achieved by the constant operation of a pump incorporated within the tank. The tank may be shaped to the contour of a man’s back or may be provided with a contoured shield.

sprayer, pneumatic. Synonym of compression sprayer.

sprayer, stirrup-pump. Sprayer held within a bucket or similar container by an adjustable foot-stirrup or fitted into a tank (also known as “bucket-pump sprayer”). Single- and double-barrelled types are available; the basic principle is the same in both. The single-barrel type consists of a barrel, a hollow plunger-shaft moving within the barrel (which acts as an air chamber), a plunger, and the necessary valve assembly. In the double-barrelled type the main barrel forms the air chamber, with the pump and plunger in a second barrel alongside. The plunger in both cases is operated manually by an up-and-down movement within the barrel.

spraying, barrier. Spraying in an area of predetermined shape and size to protect the population living in and beyond the sprayed area.

spraying, focal. House-spraying carried out in strictly localized areas such as one house or a group of dwellings; or in localities classified as either residual or new foci of malaria. During the consolidation phase focal spraying is an activity of surveillance operations.

spraying, residual. Spraying of a residual insecticide.

spraying cycle. Repetition of spraying operations at regular intervals; often designated in terms of the interval between repetitions, e.g., a six-month spraying cycle, one in which spraying is repeated after a six-month interval. Not to be confused with spraying round.

spraying frequency. Number of regular insecticide applications per house per year.

spraying interval. Time elapsing between successive applications of insecticide.

spraying round. Single spraying of all sprayable houses in an area over a period of time. Not to be confused with spraying cycle.

spraying squad. In malaria eradication terminology, the basic operational unit for spraying operations, composed usually of two to six spraymen under a leader. (112)

sprayman. In malaria eradication terminology, the employee responsible for identifying and spraying the sprayable surfaces in the houses assigned to him by the squad leader and for correct utilization and maintenance of his equipment.

sprayman workrate. Average work output of a sprayman, usually expressed as the number of houses or the number of square metres sprayed per working day.
stippling. See under James's stippling; Maurer's spots; Schüffner's dots; Ziemann's stippling.

stirrup pump. See under stirrup-pump sprayer.

strain. Population of the same stock descended from a common ancestor or derived from a single source. Strains behaving in a similar manner are homologous; those behaving dissimilarly are said to be heterologous. (123)

subspecies. Population of organisms originally belonging to the same species but so isolated by geographical barriers from other populations of the species as to have undergone taxonomically significant genetic divergence. Forms accorded the rank of subspecies are distinguished in nomenclature by a third name, so that the full designation is trinominal. (120)

superinfection. Fresh infection brought about in a host while a previous infection with a parasite of the same species is still present.

suppression. See under suppressive treatment.

surface-active agent. Substance which, when present even in very low concentration, lowers the surface tension of its solvent. Typical effects of surface-active agents, or "surfactants" (also known as "wetting agents"), are the functions of wetting, foaming, dispersion, emulsification and detergency.

surveillance. In malaria eradication terminology, that part of the programme aimed at the discovery, investigation and elimination of continuing transmission, the prevention and cure of infections, and the final substantiation of claimed eradication. The individual functions of surveillance are case detection, parasitological examination, antimalarial drug treatment, epidemiological investigation, entomological investigation, elimination of foci by either residual spraying or mass drug administration, case follow-up and community follow-up. (115)

survival probability of. Mathematical expression of the likelihood of a female anopheline remaining alive for a specified period of time.

susceptibility. 1. Liability in a population of insects to be killed by a particular insecticide. The average susceptibility of a species or population of mosquitoes is usually measured in terms of the median lethal concentration (LC50). (75-77) 2. Liability of a species of mosquito to become infected when fed on a person known to be infectious; usually measured in relation to the liability of infection of another species fed at the same time on the same person. 3. Liability of a person to become infected. The lower the immunity, the higher the susceptibility.

suspected case. See under suspected case.

susceptibility. Ability of a substance to enter into and remain in suspension. The susceptibility of an insecticidal water-dispersible powder is measured by the amount of insecticide which remains in suspension for a given time under specified conditions after having been submitted to a treatment simulating tropical storage. (99)

swarming. Nuptial flight or dance in which 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 without horizontal progression; the females fly into the swarm of males, and copulation takes place in the air.

swath. Strip or band of fluid produced on a surface by the use of a sprayer. In house-spraying, a swath may be applied while the sprayerman stands still and moves the lance vertically ("vertical swath") or (less commonly) while the sprayerman walks parallel to the wall holding the lance at a given height ("horizontal swath").

swath width, effective. Distance between centre lines of successive properly sprayed swaths; it is equal to the swath width minus the overlap.

synergism. Joint action of non-antagonistic substances. As applied to drugs, there are two main types of synergism: addition, in which the combined effect of the drugs is equal to the sum of their separate effects, and potentiation, in which the combined effect exceeds the expected sum of their separate effects.

tank charge. Quantity of insecticide formulation (water-dispersible powder, emulsifiable concentrate or technical product) required for each filling of a sprayer. For water-dispersible powder, the insecticide tank charge should be weighed and distributed in paper, plastic or cloth bags. The amount of liquid charge is usually between one-half and three-quarters of the total capacity of the tank.

tenue form. Appearance characteristic of certain strains of *P. falciparum*, brought out in rapidly dried thin films. (13)

tertian. Recurring every other day (every 48 hours). See also tertian malaria.

tissue stages. Schizogonic stages of malaria parasites occurring in cells other than erythrocytes in the vertebrate host. See also exoerythrocytic schizogony.

tolerance. 1. Effect characterized by a lessened response to a given quantum of infection, of a toxicant or of a drug. (30) 2. In insects, the characteristic ability of some species, on first exposure to an insecticide, to survive higher dosages of it than other zoologically related species which are normally susceptible. Increased insecticide tolerance may be seasonal—e.g. related to prehibernation—or may be due to a general increase in vigour affecting susceptibility to any insecticide ("vigour tolerance"). It may also at times be a sign of incipient physiological resistance to an insecticide. (77)

total coverage. 1. In case detection, activity in an area under surveillance which covers every locality and every household with adequate efficiency throughout the year or during the time when transmission occurs. 2. In mass drug administration, general distribution of drugs to a population in such a way as to assure the continuous maintenance of an effective drug concentration in the blood of every individual. 3. In spraying operations, application of insecticide during one spraying cycle to all sprayable surfaces in all sprayable houses within a given operational area.

transmission, natural. Process by which a vector mosquito transfers the parasite from an infectious subject to a susceptible recipient. From an epidemiological
standpoint, natural transmission may be perennial (when transmission occurs throughout the year without great variation of intensity), subperennial (when it occurs throughout the year with peaks of markedly greater intensity in some months) or seasonal (when it occurs only during some months and is totally interrupted during other months). From an operational standpoint transmission continuing during eradication measures may be either residual (when it still persists in spite of the application of interruptive measures) or renewed (when there is recurrence of transmission in areas where it had been previously interrupted).

**transmission season.** Period of the year during which natural transmission of malaria infection can normally take place.

**trap breeding place.** Artificial breeding place constructed with the purpose of collecting mosquito eggs or larvae.

**trap hut.** Structure adapted for trapping mosquitoes attracted by bait (human or animal) placed inside it. Its purpose is either to collect a representative portion of the incoming mosquitoes or to test the effectiveness of an insecticide. It is usually a hut of simple design, often built of the same material as the local habitations, provided with trapping devices—usually one or more window traps so that mosquitoes may be trapped as they enter or leave. (71)

**treatment, anti-relapse.** Treatment aimed at the prevention of relapses, particularly long-term relapses. (88)

**treatment, presumptive.** Administration of an antimalarial drug or drugs, usually in a single dose, in suspected malaria cases before the results of blood examinations are available. Its principal objectives are relief of clinical symptoms and prevention of transmission. (90)

**treatment, radical.** Treatment adequate to achieve radical cure. In vivax, malariae and ovale infections, this implies the use of drugs which destroy the secondary tissue stages of the parasite. (88, 90)

**treatment, suppressive.** Treatment aimed at preventing or eliminating clinical symptoms and/or parasitaemia by early destruction of erythrocytic parasites. It does not necessarily prevent or eliminate the infection, and overt malaria may develop after drug withdrawal. (87, 88)

**treatment schedule.** Scheme of administration of a drug.

**trophozoite.** Strictly, any asexual and growing parasite with undivided nucleus. In malaria terminology, generally used to indicate intracellular erythrocytic forms in their early stages of development. Trophozoites may be in either a ring stage or an early amoeboid or solid stage, but always have the nucleus still undivided. (13)

**vacuole.** Portion of the young parasite, usually near the centre, showing very faint staining or none and surrounded by a circle or semicircle of cytoplasm.

**vector.** In malaria, any species of mosquito in which the plasmodium completes its sexual cycle in nature and which is thus able to transmit the disease.
GLOSSARY

vector, conditional. Species of mosquito known to transmit malaria but presumed to be incapable of maintaining endemic malaria in the absence of more efficient vectors.

vector, principal. Species mainly responsible for transmitting malaria in any particular circumstances. Principal vectors may overlap or may alternate seasonally.

vector, secondary. Species thought to play a minor role in transmission in association with a principal vector and to be capable of maintaining malaria only at a reduced level in the absence of the latter.

vector control. Measures of any kind directed against a vector of disease and intended to limit its ability to transmit the disease.

vector efficiency. Ability of a mosquito species, in comparison with another species in a similar climatic environment, to transmit malaria in nature. A rough estimate of relative efficiency may be made by comparison of sporozoite rates taken in comparable conditions.

vermicule, travelling. Obsolete term for ookinete.

vigilance. In malaria eradication terminology, a function of the public health service during the maintenance period, consisting in alert watchfulness for any occurrence of malaria in an area in which it had not existed or from which it had been eradicated, and the application of the necessary measures against it.*

vigour tolerance. General increase in the ability of a mosquito species to survive exposure to many types of insecticide, i.e., a decline in the normal susceptibility depending on a non-specific defence mechanism.

voluntary collaborator. Person belonging to and permanently present in the community who is not a paid staff member of the malaria eradication service but who co-operates voluntarily in surveillance activities such as case detection, notification and treatment. For operational purposes voluntary collaborators are regarded as malaria detection posts. (115)

water-dispersible powder. Insecticidal formulation consisting of the insecticide, together with suitable carrier(s) and surface-active agent(s), designed for suspension in water. (99)

wettable powder. Colloquial term for water-dispersible powder.

wetting agent. Synonym of surface-active agent.

window trap. Type of removable insect trap fitted to an opening of a typical inhabited or experimental hut and used for collection of incoming ("inlet trap") or outgoing ("outlet trap") mosquitoes. (71)

xenodiagnosis. Exceptional method of diagnosing malaria in the suspected vertebrate host by feeding vector mosquitoes on him and subsequently examining the mosquitoes for the presence of sporogonic stages of the malaria parasite.

* In Spanish-speaking countries vigilancia is used to express the activities both of surveillance and of vigilance proper.
Ziemann's stippling. Granulations brought out by special staining in erythrocytes infected by *Plasmodium malariae*.

**zone.** In malaria eradication terminology, a territorial and administrative operational unit responsible for the operation, evaluation and administration of the field programme in its area, which often coincides with an administrative division of the country. The zone office is normally under the direction of a senior professional officer, responsible for execution of all operations and routine evaluation of results in the zone. (107)

**Zoological Nomenclature, International Code of.** Code of rules established by the International Commission on Zoological Nomenclature and periodically revised. (119)

**zoonosis.** Disease or infection common to man and other vertebrates and naturally transmitted between these hosts.

**zoophilic.** Term applied to mosquitos showing a relative preference for non-human blood even when human hosts are readily available.

**zygote.** Product of the union of the male and female gamete; term formerly used incorrectly to designate the oocyst.
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