Malaria.

By,

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On the Nature of Malaria and its Prophylaxis.

During the last five years, having, in the course of my duty as a Medical Officer of Her Majesty's Indian Army, been called upon to serve in climates and conditions so widely differing in locality and circumstances, as Afghanistan and Upper Burma, and having seen how the troops suffered from malarial fevers equally on the elevated sandy plains and bare rocky passes of the former, and in the dense jungles and swampy valley of the latter, it has appeared to me not unimportant to inquire into the nature of this "malaria", which can exist and operate under such extreme variations of scene and climate, and cause such diverse results in the persons of men exposed to its influence.

The importance of fully understanding and studying malaria, would have been forcibly impressed on the mind of any
any one, however unobservant, who might have had cause to enter any of
the base hospitals established at Mandalay and Rangoon, for the treatment of the
sick and wounded of the army engaged in the late Burmese Campaign. In these
hospitals were gathered all the most serious cases, brought down from the immemorial
detachment hospitals scattered over the length and breadth of Upper Burma, so that
here could be studied in all their varied types, remittent and intermittent fevers, and
that Malarial Cachexia which is often worse than either, in the slowness and incomple-
teness of its cure. For the greater part of the sickness of an army serving in a tropical
or sub-tropical country, is due to the action of malaria; and the amount of invaliding
and death from this cause alone, far exceeds that from wounds and all other
illnesses put together.

Many historical examples of the havoc wrought by this mysterious pestilence
might be given from the campaigns in which British troops have been engaged.
from the time of the Walcheren expedition, down to that recently brought to an end in Upper Burma. In the former expedition, out of 41,000 fighting men 7,000 died, and half the remainder were permanently disabled for service. (Jeggo, on the Nature and History of the March Poison. Jans. Roy. Soc. Sini. 1823 Vol. 1.)

Again we read (Administration of Scinde p. 72, Calcutta) “In Scinde every officer and every man of Sir E. Napier’s army of 17,000 men, was attacked with fever. In some regiments no surgeon was able to visit the hospitals, and the force was reduced to such a state that, had the hill tribes made a raid, they might have plundered the whole country, as scarcely a man could be found fit for duty.”

I could give many illustrations of quite as striking a nature, from my own experiences in Afghanistan and Burma, but the following must suffice.

On the 17th of January 1857, two companies of the 25th Bombay Light Infantry—composed mainly of well-built sturdy Mahuttoa—were sent to occupy the outpost of Pyintha.
Pijintha, situated on a ridge at the edge of the Shan Plateau, 3,000 feet above the sea, and about 30 miles east of Mandalay. The site had been carefully chosen, the dense jungle, covering the hills, cut down all round for a distance of 200 to 300 yards, and in every way the sanitation of the place and the health of the men scrupulously attended to, in so far as the exigencies of the case and the necessities of active service, in a densely wooded district admitted. In spite of all precautions however, it was found necessary to relieve the men on the first of May, and these men having only been 3½ months in the place, were judged to be so malaria-stricken, that, on their arrival in Mandalay they were relieved from all duty for a month, to enable them to regain their health, if that were possible without a change of climate. And it is to be remembered that it is of men similarly affected that Sir James Macgrigor writes: "In making calculations
of efficient force, this description of men could not be relied on for operations long continued in the field, for we found that in those who were convalescent, or barely recovered fromague, the causes next prone to reproduce the disease, were exposure to a shower of rain, or wetting the feet, full exposure to the direct rays of the sun, or to cold, with intemperance, irregularity or great fatigue, to all of which the soldier is of course liable in the discharge of his ordinary duties. Nor did the 5th Bengal Light Infantry, who succeeded the Bombay regiment, fare better. Two companies, of the strength of 145 rank and file, arrived at Jintia on the 4th of May, in full strength and vigor. The malarious climate told quickly on them, and at the end of July, just three months after their arrival—they also had to be relieved. They had become so reduced in strength as to be hardly fit to carry their rifles, and when sent on escort duties had to be mounted.
mounted on ponies, being unable to march. When the garrison was relieved they numbered barely 70 men—of whom 24 were in hospital—so reduced were they by sickness and death. Other examples might easily be given, but I think enough has been said to demonstrate the disastrous results of this malarial poison—"the very Destroying Angel" as MacCallum calls it—on the persons of those exposed to it, and the extreme importance to the army surgeon of understanding fully its nature and mode of origin.

It is not only among armies however that malarial fevers are to be met with, but likewise among the civil population, causing "an amount of sickness and mortality which is hardly credible, and in some years almost challenging comparison with the Black Death which ravaged Europe in the fourteenth century and destroyed a fourth part of the whole population. The registered deaths from all causes in India in the year 1879 were
were 4,975,042, of which fevers accounted for 3,564,035, or thirteen times as many as from cholera; though it may probably fairly be estimated that not more than 50 per cent of these deaths were due to endemic fevers (Sydenham, Climate and Fevers of India, p. 13).

I propose then in the following pages to discuss the subject under the following heads, viz.:—

I. What is Malaria?

II. Is it possible to render a malarious locality healthy?

III. If not, can man's power of resistance to the malarial poison be increased?

I. What is Malaria?

Malaria is found to prevail over a great part of the earth's surface, being found more or less everywhere between the parallels of 65 north and 30 of south latitude, and being always most virulent in tropical countries. Its vertical distribution, i.e. the heights above sea level at which it may be
met with, is stated by Professor Atten to be from 400 in Europe, to 3000 feet in India; but it can undoubtedly exist at much higher levels than
this, as was exemplified in the case of the troops stationed at Quetta — which is over 5,000 feet above sea level
who suffered much from malarial fevers, before the new water supply was brought in. I myself saw a
most virulent outbreak among
the troops serving in Kashmir and
the Indus Valley, though these localities are quite 1000 feet higher than Quetta.
So widespread is this malarial poison
that as Parkes says "when a climate is
called unhealthy, in many cases it simply
means that it is malarious." But yet it
is not equally distributed over every part
of the country, but is noted as being more
intense at one part than another: e.g.
the district at the foot of the Himalayas
known as the Terai, has such an evil
reputation, that, travellers obliged to
cross it, do so by a forced march during
the day, so as, if possible, to avoid spending a night exposed to its malarias influences. From the earliest times too, the neighbourhood of marches has been known as a breeding ground for malaria, and this more especially since the times of Lomeci of Rome, who in 1893 published his great work (De morbis paludum effluviis et mala malaris), tracing the connection between intermittent and remittent fevers, and the paludal or marsh miasmata. From that time till quite recently, the "paludal prejudice" as Tommasi-Budelii calls it, has bidked out largely in the mind of the profession the fact being apparently overlooked that malarial diseases may exist in most virulent forms in districts far removed from marches.

The following examples are chosen as demonstrating the great variety of soils and situations where malaria has been found.

1. Lowlying water-logged ground, valleys, etc.
2. Soils drying up after rain, and exposed to hot rivers.
3. Soils rendered damp by the damming of watercourses, interrupted drainage, or irrigation in excess of plant requirements.
4. Dry, sandy or rocky soil, baldyng or Elevated.
5. Ground where hemp, jute, indigo or other similar vegetable matters are cultivated.
6. Jungles, deltas, and lowlying lands along the coast where salt and fresh water mingle.
7. Land newly broken up, or denuded by jungle.
8. Rocks, which from their structure are permeated by moisture, or the debris of such.
9. Hills of moderate elevation, covered with jungle, and the tract along the foot of hills known as the Terai.

We see then under what diverse conditions this poison can exist, no soil apparently being unfavourable to its development, for it is found prevailing in such various soils as sand, alluvium, clay, ferruginous granite, ironstone etc. What sort of agent can this be that develops energy under such different conditions, which can infect the soil of any country, however that soil may differ from other

Two principal theories have been advanced as to the cause of malaria, viz. (1) that it is an emanation from the soil either gaseous or particulate; or (2) that malaria as an entity has no existence, but "that all the effects produced by so-called malarious influence may be caused by the rapid abstraction of animal heat without the intervention of any specific microbe." (Oldham, What is Malaria? p. 66.) Surgeon-Major Oldham of the Indian Medical Service has written an elaborate work on this subject, in which he seeks to prove that intermittent fevers are due solely and simply to changes of temperature and climatic vicissitudes; and in this view several Indian authorities are inclined to agree with him. Lately this has again been advocated by Dr. Baker, (Malaria and the Eruption of Periodic Fever, by H. B. Baker M.D.; Jour. Amer. Med. Assoc. Nov. 10th, 1888, p. 661) but as
Tayler says (Climate and Fever of India, p. 31) "though there is much in observation of disease in India to support this view, it is doubtful if it is adequate to produce periodic fevers in those who have not previously been exposed to certain other, i.e. malarial influences." A strong argument against this theory exists in the fact that formerly agues used to be very common in England and some parts of Scotland (e.g. the case of Gower) where they are now quite unknown, or regarded as great rarities when they do appear, and this without any known change in the variations of the thermometer. Again there is the historic case of the Roman Campania, where formerly the wealthy Romans used to retire during the heat of summer at the very season when now, no one can live there without certainly contracting malarial fevers if the most pernicious type. Has then the climate of modern Italy so much deteriorated, or is it not more likely that some other cause than "chill" must be sought for as the origin of malaria?
We know also of most equable climates, where fevers render the country almost uninhabitable; one example must suffice. The shores of Lake Nyassa notoriously malaria so much so that, as Dr. Herr Cross of the Livingstonia Mission reports, (Letter. 24th 13th. 1888, in the Church Monthly for April 1889) "I doubt if any part of the lake shore can be called healthy, for it is quite evident that for generations past the lake has been subsiding, and has left all along its shore large plains of ten or twenty miles in extent. These while very fertile are marshy and cannot be occupied by white men." And yet this is the region spoken of by Professor Drummond as being remarkable for its equable climate. He says (Geographical Africa p. 226) "At Lake Nyassa 85° F. is a common figure for mid-day in the hottest month (November) of the year, while the average night temperature of the coldest month (May) is about 60° F. The lowest registered temperature at the Lake has been 54° and the highest - though this is extremely rare - 107°. Well attested facts such as the following also
also require explanation viz. that the blood of a person suffering from malarial fever is capable of setting up true intermittent in another person who has never previously suffered from it. (Marchiafava md. Letici, Archivio Italiano di Biologia, June VIII p.130) and that "cases of intrauterine malarial disease have been observed" in which children have been born with enlarged spleens and all the evidences of malarial cachexia, which yielded to treatment by quinine. (Wright in Zimmeru Cyclopaedia Vol II p.398)

I conclude therefore from the above facts, and others that might easily be quoted from the writings of Leitch, Maclean, Tomasi-Cudeli, Dumon and others, that "chill" as the originator of malarial disease, has no sure foundation in experience, and that those who deny the existence of malaria "have a difficult thesis to maintain".

Let us now take up the other hypothesis viz. that malaria is an emanation from the soil, and see whether it can be made to fit into the known facts and modes
modes of action of the poison. That it is from the soil - or water impregnated with the poisonous products of this soil - that the infection comes, has been held by most authorities of note from the earliest times. Leon Colin, a French military surgeon who studied malaria carefully during the time of the French occupation of Rome, calls it in preference to malaria, "intoxication tellurique" as indicating its origin, and Tommasi Redi says that "all our knowledge of malarious diseases proves that their true cause must be sought for in the soil of the places chiefly affected;" (Copenhagen Soc. Selecta Monograph 1858, p. 2) and we find that when the soil is covered over so that no emanation can arise from it, malarious diseases practically cease; and on the other hand, when the soil is disturbed and freely turned up, so as to set free any poison that it may contain, that then an aggravated type of malarial fever at once prevails.

A good example of the former is instanced by
by Cradl (January 1854). In 1853 he caused the grounds of the Jemichian Hill near
the Palazzo Salviati, in the Lungara, to be well drained, and where not
paved, to be covered with a layer of
earth brought from a healthy locality.
Since then no case of fever has occurred in the Military College in the Palazzo
Salviati, while in the neighbouring Palazzo
Corinini on the same side of the Lungara
while nothing had been done, numerous
cases of fever had occurred, some
proving fatal. The well known fact
that as long as a marsh is kept full
of water, it is comparatively harmless,
but that when the water evaporates and
expands the fully saturated land beneath,
then malaria or rice becomes ripe, is
another example of the same thing.
This of course applies to the case of
paddy fields, which are harmless as long
as the young rice is growing, for they
are then kept full of water, but become
sources of infection whenever the water
dries up.
As instances of the sudden development of malaria which takes place on disturbing the ground, may be quoted the case that happened at the Island of Hong Kong, narrated by Prof. Maclean in his work on Tropical Disease. Before the cession of the island it had been occupied by troops who enjoyed good health; but no corner was it ceded than excavations begun for the foundations of barracks etc. At once it became fearfully unhealthy from a form of remittent fever of great malignancy. I well remember writes Professor Maclean the following painful occurrence. A small house was occupied by some artillery officers; one of them, a young and inexperienced subaltern, impatient of the want of space behind the house, had the side of the hill excavated away, exposing a considerable surface of soil. The result was, that all the inmates of the house were at once struck down by the prevailing fever, and the young officer
officer, the unconscious author of the mischief, fell a victim to it." It is universally acknowledged in India, where indeed it is a matter of popular remark, for if a person removing to a healthier locality, the natives say he has gone to "change the water" not as we have it "for change of air." Numerous cases in India prove this to a demonstration.

At Peshawur—the second largest military campment in India—remittent fever formerly raged with such virulence in the autumn, that regiments exposed to it were quickly rendered unfit for service, but now since the new water supply has been brought in, it has become a comparatively healthy station.

The same result followed the introduction of pure water at Dulta, as noted above.

Athen reports of the Wynnead district of Southern India, that "in one village there were two sources of supply—a tank fed by surface water and marsh, and
and a spring—these only who drank the tank water got fever." In certain other villages reported as being "notoriously unhealthful," wells were dug, and the fevers disappeared and have not since returned. (Pratt's Medicine, p. 324, 1872)
Again people drinking water of streams draining forest lands or rice fields, are noted as suffering more from fever than those drinking water from wheat lands.

In the Abyssinian expedition, Dr. Blake and Mr. Prideaux while marching from Massowah to the high lands, a distance of over 500 miles, drank nothing but tea or chocolate, and enjoyed perfect health; while Mr. Rasam, less strict, suffered from fever till he followed their example, when he too remained free from fever. Their servants who drank water and took little care with it, were all ill with fever and dysentery.

The villagers of Bahrawa formerly used water from shallow wells fed by surface drainage, repeatedly had to
dwell their homes from the fatal
form of fever prevalent amongst them;
a well of masonry, 40 feet deep, was
constructed, and the village has
become one of the healthiest in the
neighbourhood. The Forest Department
now constructs deep masonry wells
at all their stations, and their em-
ployees can now remain permanently
at stations at which formerly they had
to be relieved once a fortnight" (Bunce, p. 19).

We may then, I think, take it as abun-
dantly proved that malaria arises in
the soil of infected localities; but we see
now whether there is any evidence
pointing to its nature being either gaseous
or corporeal.

If it were of the nature of a gas we should
expect to find it most abundant in
the air during the day, when the earth
is hottest and evaporation strongest.
But on the contrary we know that the
most dangerous times, i.e. the periods
during which the poison is presumably
most abundant in the air, are just after
sunrise.
sunrise and after sunset, when the difference of temperature between the earth and the lower stratum of the atmosphere is greatest, and when therefore the currents of air ascending vertically from the soil to the upper atmosphere are strongest. If the poison is formed of solid particles of low specific gravity such as germs of vegetation or organisms then it is precisely at these times that they ought to be present in the lower stratum of the atmosphere.

Again we see how, in valleys, from which mist rises at night to the extent of enveloping tall objects, such as trees or towers, the malaria does not rise to the full height along with it, for people sleeping there are comparatively safe if elevated only a few feet from the ground even though surrounded by the mist; evidently then it cannot be a gas or it would diffuse itself as widely as the mist, as we see that the products of putrefaction do, for they can be easily detected by the smell which such fog often has.
That the poison does exist chiefly in the lower stratum of the atmosphere is a well known fact, recognised by the natives of many malarious countries who always sleep in houses raised several feet from the ground.

The Tharus of the Terai, for instance, live in houses built on piles 6 to 8 feet high, and the same custom is universal in Burma.

During the late campaign in Upper Burma, advantage was always taken of these elevated houses and Thongyi Hyauings (Buddhist monasteries) for the accommodation of the troops when marching, and I on one occasion saw a most striking example of the benefit of this practice. Two columns of 150 men each, started from widely separated base points and moved on Siew, a village close to the western frontier of China beyond Ahamo.

The northern column arrived a day before the southern one, and took up its quarters in a large wooden hyauing elevated eight feet from the ground.
The southern column of which I was in medical charge, had, on arrival, to be quartered in the bamboo huts in the village, which were raised barely two feet from the ground; in all other respects the situation of the two columns was the same as regards proximity to jungle and river. Yet while the northern column had hardly one sick man, the troops of the southern column became very sickly and had an average attendance at hospital of between thirty and forty daily. This could only be accounted for by the difference of elevation of the houses, and it was noted that those of the southern column for whom accommodation was found in the baungs, were perfectly healthy. The Lushais, who live in a country intersected by deep valleys, always avoid sleeping in them if possible, but when obliged to do so, invariably construct a well elevated machan (platform) in a tree.

In Italy too, the peasants often sleep
on top of old sepulchral monuments in the unhealthy season, and are thereby enabled to inhabit places in which they could not remain if obliged to sleep on the ground. Further evidence against the gaseous theory is furnished by the manner of spreading of the poison, for it does not spread itself out equally on every side from an infecting focus, as it would do if it were a gas, but follows the line of direction of the prevailing wind as would naturally be expected were it composed of solid particles.

A line of trees too affords protection from infection, when placed between a house and marsh - just as it affords shelter from the wind - which could hardly be the case were the poison a diffusible gas. We find then, that the evidence of experience points in the direction of the poison being of a corporeal and perishable nature, and not a gaseous imperishable thing.

When we remember the fact - fatal to the chemical
chemical theory—that the malarial poison remains uniform in soils of the most diverse kinds, and may be produced from any soil, no matter what the composition of such soil may be; it at once suggests the idea that it must be due to some living organism. For as Darwin has shown, this adaptation to surroundings is a property of living things, and one of the factors in the production of new species.

Dallinger too, has lately shown that this applies equally to low forms of life, for he succeeded in cultivating organisms, at a temperature far above or below that at which they ordinarily flourish, by the simple process of gradually and very slowly raising or lowering the temperature.

Again we see as Tommasi-Bordeli says (Syd. Soc. Sel. Monograph p. 9) that "when man's industry ceases to remove the external favouring conditions of malarious production, this assumes such vast proportions as are inconceivable.
inconceivable without the existence of an organism capable, when its evolution is no longer checked, of infinite multiplication. This enormous increase is historically proved, especially in Italy, but likewise in other countries as well. (see Oldham, p. 16) "The conception of a living organism, which finding no check to its development, has the power of extension by an infinite number of progressively increasing generations, seems to fit best the magnitude of the phenomena."

Then too, peat bogs are well known never to be malodorous, for the tar, creosote, tannin, volatile oils and resins contained in peat act as antiseptics, preventing the development of the organisms. This antiseptic action would account also for the immunity of the charcoal-burners in Bassam, for it is noted by Meredith (p. 14) that those who live near the pits, breathing the smoky air, are free, while their fellow workers living at a distance...
distance are affected.

Sonderman, whose experience of jungle life, as Superintendent of the Government Elephant Catching Operations in the Garo Hills, Assam, is immense, recommends (thirteen years among the Wild Beasts in India) that a fire be lighted to windward of a moving camp in the jungle as a preventive of malaria.

Here then we have evidence accumulated from very various sources, pointing strongly in the direction of an organic origin for the poison; and we find—even before the present development of microscopic science had directed attention so strongly to micro-organisms as a source of disease—that various scientific men (Häcker 1802, Limneus 1778) had surmised that some low form of organism might be concerned in the production of malaria. (p. 126) Mitchell of Philadelphia in 1849 upheld the same view. In 1866, D. Salisbury of Ohio, (Am. Jour. med. sci. Jan. 1866) found in the saliva of four patients, small elongated cells, single
or arranged in rows, which he identified as the spores of an alga of the species Palmella, found growing in marshes and in clods of malarial earth, and which he was also able to collect from the air of those regions by means of glass plates smeared with glycerine. By placing fresh clods containing this alga on the sill of an open bedroom window, he, on two occasions produced intense attacks of intermittent in the persons of the inmates. But, granted that the fever was due to the earth, he omitted to prove the absence of other organisms from the clods, and it has been stated by Starkness (Brit. Med. J., Jan. 1869) that he found identical spores in the snow on the summit of the highest hill where no cases of malaria is unknown, and Longi and Ferrigl seldom found them in the stagnant water of the Campagne and never in the air.

In 1869 Dr. P. Balesta discovered an alga in the Pontine Marshes, which he called "alga miasmatica", declaring it to be the cause
cause of malarial fevers, but he failed in finding it in non-marshy malarious districts, and his experiments are quite inconclusive.

Various other observers describe forms found in marshes, and ascribe to them pathogenic qualities, but on quite insufficient grounds.

Griffini in 1873 tried to produce malarial fever artificially, by injecting dew from marshes, and water from rice fields, into the veins of dogs and rabbits, but though he caused a rise of temperature in the animals, yet he failed to produce true intermittent paroxysms, and the blood showed no increase of the organisms contained in the dew.

Lanzi and Ferrigi have the merit of having used a more rigorous method than any of their predecessors, and of having taken the first step towards the solution of the problem; and the discovery of black pigment in the spleen and blood of the animals experimented
on "show that they first succeeded
in procuring malarious infection
in animals." This was effected by
injecting mud, taken during the height
of summer from the marshes at Onir,
and they concluded that malaria
was a "cadaveric vegetable poison" though
they failed to prove it for they did not
separate this substance and show that
it could generate malaria, nor were
they certain that all the organisms
in the mud were dead when injected.
We now come to the famous resea-
rches of Klebs and Tommasi-Crudeli, in
which the modern idea of the parasitic
origin of malaria may be said to be
founded.
In the spring of 1879 they examined
the air of the Pontine Marshes, water
and mud from the lake of Caprolace,
and the soil of several malarious places
by various processes of practical cultivation
they succeeded in isolating a bacillus
having the following characters:—

"Rods of the length of 5–10 micromillimetre,
which
which, in developing, are converted into tortuous filaments, divided into joints by means of clear spaces in their protoplasm, or, more rarely, by dividing membranes. These filaments, in the surface exposed to the action of the air, produce rows of very short joints, and develop in their interior spores, before their division into joints, or after this has happened. These spores occupy the middle, or extremities of the joints, or both at the same time; when the division into joints does not happen they are multiplied by becoming still smaller, and the interior of the filament is filled by a granular moss" (kyd. Sci. Mem. p. 26). By injecting this bacillus, they produced fever of an intermittent type in rabbits in which after death, malarial enlarge-ment of the spleen and melaenaemia was found. The same fever and post-mortem appearances ensued on the injection of the crude material (i.e. sand, washings of soil, etc.) from which the
the bacillus was originally obtained, and this enlargement of spleen and melanæmia, was quite peculiar and different from the splenic enlargement seen in septicaemia.

They claim then “to have proved:—

1st That malarious affection may be produced artificially in animals, in the identical forms known to human pathology.

2nd That these artificially produced malarious affections are excited by organisms, which are found in the soil of malarious places, before the appearance of the fever and are even then, diffused in the strata of the air nearest the soil. (Footnote)

They also obtained from the bodies of infected animals, an organism, morphologically identical with the bacillus of the cultivations, and the crude material used for injection. This organism they have named the “Bacillus malariae”; and in the examination of the bodies of three persons dead of puerperial erysæma.
fewer, Dr. E. Marchiafava found "filaments, homogenous or uniform, of a length, equal to two or three times the diameter of the red corpuscles, and furnished at their ends, sometimes also in the middle, with slight swellings, and endowed with quick movements of locomotion, sometimes curvi-linear, sometimes zigzag." Though he surmised that these filaments might be spore-bearing bacilli, yet they were not identified as the same forms as those found by Klebs and Tommasi-Cudeli in malakia, earth, and Marchiafava expressly stated "that other studies were necessary before being able to pronounce on the nature and significance of these forms" (not our les études modernes, cit. Arch. Ital. de Biol. 15, p. 306).

Dr. Sternberg of New Orleans, however, contends that Klebs and Tommasi-Cudeli have not proved their point, and that in his hands he found that other organisms present in marsh mud were capable, after cultivation on wingless, of producing the effects observed in rabbits by the Italian...

These remarkable researches having called attention to the state of the blood in malarial patients, many observers in Italy, Germany, France and America took up the subject, the result being a most remarkable advance in our knowledge of the organisms found in the circulating blood of man and animals. The most important of these will now be noticed.

Laveran in 1881-2 communicated to the Paris Academy of Medicine the results of his observations in Algeria, (Comptes Rendus 1882) and he subsequently extended these in a large volume published in 1884. (Huitié des Récits Pathologiques Paris 1884) In it he describes organisms, which he found in the blood of 180 patients, out of a total of 192 examined by him. The twelve patients giving negative results, had already been treated with quinine before he examined them; and so we shall see later in that this drug has a most marked effect on such organisms.
organism, it amply accounts for their absence.

He describes three principal forms, viz.-
1. Crescentic motionless bodies, pointed at the ends, with delicate outline and transparent body, colourless except for a blackish spot in the middle due to pigment granules. A fine line joining the extremities of a crescent was sometimes seen.

2. Flagellate bodies. These were spherical bodies, of the mean diameter of a red blood corpuscle, containing pigment granules, which when at rest were arranged in a circle, but often showed rapid movements and lost their regular arrangement. On the borders of the spheres the fine filaments, - 3-4 times the length of a red corpuscle,- could often be perceived in rapid motion. When at rest the filaments were invisible. They sometimes were seen to become detached and move about among the corpuscles. Laueran believes that these pigmented bodies represent different stages
stage of an elementary parasite, which he is unable to pronounce to be animal or vegetable, which exists in an encysted condition, and in its perfect form becomes free as a movable filament. (Syd. Soc. Mem. 1858 p. 65)

3. Pigmented spherical bodies, transparent and finely granular, with pigment granules disposed irregularly at the periphery, or collected in the centre, and of a diameter of from 0.008 to 0.010 micra. They have no nuclei nor do they stain with carmine, which differentiates them from leucocytes containing pigment. He also noted (a) melaniniferous leucocytes (b) red blood corpuscles vacuolated in one or more spots containing pigment granules and (c) free pigment grains. These various forms he found only before and during an attack of fever. In post mortem examinations he found large numbers of pigment granules in the blood, especially of the liver and spleen, but in some cases also in the marrow and brain. (Lancet Nov 1861)
Richard of Philadelphia, Algeria, confirmed these observations (Sur le parasite de la Malaria, Comptes Rendus 1882) but maintained that the spherical pigmented bodies are developed inside the red blood corpuscles, and that only when mature do they issue from them and become free in the blood, sometimes developing filaments as described by Laveran.

These pigmented bodies had already in part been described by Freerich and Keloch, but Laveran has the credit of having first called attention to their probable parasitic nature, and Richard of having first demonstrated their existence inside the red corpuscles.

Marchiafava, who had examined the blood of those who died, for Kels and Tommasi-Budeli, along with Culbini published in 1880 (Gazz. Medico di Roma, Annovi 1881) results which tended to throw doubt on their statement, that the Bacillus malariae was to be formed in the blood of malarial patients. In the summer of 1882, Marchiafava and Dr. Ferraresi made investigations at the hospital of S. Giovanni, into the
blood of persons suffering from malarial and other fevers. The result of these researches proved, that the forms described in 1880 and supposed to be the bacillus malariae, were only filaments arising from the inside of the red corpuscles, and which were in great part detached owing to the heating of the blood, while the small glass tube, in which it was placed for subsequent observation, was being closed. The same forms have also been described by Marchaud (H универсальная серологическая мальария. Rich. Arch. 1880) and Ziebel (Fingerbeobachtungen über den Bacillus Malariae. C. Med. Woch. 48) but subsequent observations showed that "their parasitic nature was only apparent. Many such are figured in books on histology (Hey, Ramée, de) and are well known to depend on the mode of preparation, and chiefly on the action of heat." (Geb. Soc. Memo. 477) This result, and the complete difference of appearance between their forms and the bacillus of HeLa and Immuno-Bredeli was pointed out by Marchesina, at the International Health Congress at Geneva.

In the autumn of 1883, having thus divested themselves of all preconceived notions
on the subject, Professors Marchiafava and Dr. Celli of Rome began anew the study of malarial blood, using the most recent methods of staining and cultivation devised by Koch, Ehrlich, Weigert, etc. As the result of their researches carried on for several years, they note that the most constant appearance in malarial blood is the presence in the red blood corpuscles—and occasionally but only rarely in the plasma—of actively moving amoeboid bodies. In 120 cases of recent malarial infection examined by them, these bodies were never absent. They consist of little masses of homogeneous protoplasm, varying in size from 13 to rather more than the size of a red blood corpuscle. They are endowed with active amoeboid movements, constantly changing their shape and sending out prolongations which are occasionally seen to ramify. When they cease to move they become rounded, and in the centre a dark spot appears, gradually decreasing in size as it
it becomes more distinct and finally assuming the colour of the containing corpuscle. This appearance is caused by the body becoming bi-concave, and so permitting the colour of the blood corpuscle to be seen through it. The body then expands and contracts for a longer or shorter time before becoming finally quiescent. These bodies exist in the red corpuscles, not as Laveran maintained adherent to the outside, for their pseudopodia never pass beyond the bounding wall, and they may be seen swimming freely in the protoplasm of the corpuscle, disappearing and reappearing as they rise and sink in it, and turning around. Sometimes the bodies appear outside the red corpuscles, as though entering or leaving them, but in these cases their form is always rounded and immobile. In dry preparations treated with methyl blue, the bodies are distinctly stained, and appear either as rounded and uniformly coloured globules, or oftener as rings in which are seen the substance of the red corpuscle, or a clear
clear circumscribed space. On double-staining the dry blood with alcoholic solution of safranine and methyl blue, the bodies are coloured blue while the blood corpuscles appear rose red. In certain phases of movement and when immobile, they present two parts, exterior and interior.

The exterior, thicker and very brilliant, emits the pseudophodia, and stains darker than the interior.

The central part is less brilliant, often finely granular, and is thin and clear enough to allow the protoplasm of the red corpuscle to be seen through, appearing as a clearly defined faintly coloured nucleus.

It is not easy to find these bodies in blood examined cold, but they may be well studied when the blood is kept at a temperature of 103° to 109° F.; but even at ordinary summer temperature the movements may be seen to continue for from 20 to 40 minutes. In the blood corpuscles may often be seen Bacillus-like bodies and...
and in the capillaries, coloured bodies of various shapes, which are simply the organisms seen on edge, or arrested in some phase of movement. These non-pigmented hyaline forms may be the only appearances found by which the blood may be certainly known to be malarious, or they may occur along with the pigmented bodies of Leucon; the more recent the infection, the fewer pigmented forms apparently are found, for they are probably the more natural form. Professor Golgi concurs in this view, for he found in cases of quartan fever occurring in autumn, and therefore more generally chronic, that out of 38 cases, in four only were no pigmented forms found; and he therefore regards the pigmented bodies as characteristic of advanced malarial infection. (Archives de Biologie, tome VIII, p. 155.) Marchiafava and Celli in a later paper (sur le mal maliere) note that in cases occurring in winter and spring, which are mainly of tertian or quartan type, the pigmented bodies greatly preponderate.
Generally the red corpuscles containing the bodies appear normal and elastic, but sometimes they are smaller, crenated and dark yellow; sometimes though not crenated they are smaller and have a distinct dark outline. When the bodies take up granules of reddish or black colour, and, still showing amoeboid movements, assume various shapes and forms; when these cease to move they become round, and then appear as described by Laveran, who regarded the pigment as an integral part of the parasite, and not as being formed from the haemoglobin of the corpuscle by its vital action, as has been proved by Marchiafava and Celli (in the opusculum Melanoma, Ed. Soc. Nat. Mon. 1889). For they saw granules of the colour of haemoglobin in the interior of the bodies, which subsequently become black and converted into melanin. The bodies sometimes divide and form a congeries of corpuscles, the pigment gathering in the middle; this, no doubt, represents the mode of multiplication of the
the organism, for they saw these corpuscles becoming free in the plasma and thereafter none of the dividing forms were to be found, but only bodies corresponding in size to the split-up corpuscles. This segmentation and ultimate scattering through the plasma, may take place also in the unpigmented forms.

Professor Camille Gulgi of Pavia, has made a special study of these segmented forms (sublimation melanique) and has come to the conclusion that they represent the mature condition of the pigmented bodies and he also maintains that some if not all of the latter are derived from the unpigmented forms. The cases he studied were chiefly severe quartan fevers, but also included some quotidian, tertian and irregular types. From observation of these he formulated the following laws:—

1st. Gradual development of the pigmented bodies till the substance of the red corpuscle completely disappears, in the
course of the two days of apyrexia, lasting till 6-10 hours before the
new attack.

2nd. Successive transformation of the pigmented bodies, which have re-
placed the red corpuscles (found which remains perhaps a transparent enve-
lope, formed of the residue of the globular stroma without haemoglobin)
in which the pigment, scattered abroad at first, gradually collects in the
centre, while at the periphery a process of segmentation is noted as going on.

3rd. Rather rapid disappearance of the segmented bodies during the febrile
paroxysm, so that no trace of them is to be found at the end of the period
of apyrexia" (Galpi 183)

Be also noted that the numbers of pig-
ment granules are to be found in
the leucocytes during, and after the
height of the fever, which is what
one would expect to find, when it is
remembered that it is then, that the
granules are set free by the segmentation
and dispersion of the bodies. Golgi believes that the bodies after dispersion are retained in the spleen or other internal organ, to reappear before the next attack of fever, as colourless forms. And he agrees with Marchiafava and Celli in thinking that they represent a new generation of parasitic elements. Marchiafava and Celli in their most recent memoir (Sur l'infection naturelle, Arch. ital. medic. 1888) note that Golgi's bodies are to be found before single and double tertians and quotidian, as well as in quartan fevers. The segmentation usually takes place when the red corpuscles have been nearly or altogether destroyed by the parasite; but in pcrnicious fevers, early division ("division précocce") takes place before the red corpuscles are nearly destroyed. Another mode of division is by a process of vacuolation of the body, inside which new hyaline forms arise. We have seen above how the bodies derive pigment from the haemoglobin of the blood.
blood corpuscles, and cause their death, but often also the corpuscles die without this extraction of pigment, for they may be seen, shrunken, crenated, of a dark yellow colour and containing unpigmented elements. These bodies may be seen inside leucocytes, and on one occasion Marchiafava and Celii saw the process of inclusion actually proceeding; and no doubt this is the mode - or one of the modes - of removal of these, as well as of the granules of pigment. Along with the hyaline bodies are sometimes found a variable number of little round bodies, highly pigmented, which have the appearance of micrococci. These are only distinctly seen in coloured preparations, and they may perhaps be the early stage of the hyaline bodies.

The eresencephic forms described by Laueran were also found by them, mostly human in chronic cases.

The other element noted by Laueran
vig, the flagellate organism, was seen only in rare instances; on one occasion contained inside a red blood corpuscle, but usually free in the plasma. There were never more than two or three on a slide, they varied in size from a half to nearly equal the diameter of a red corpuscle, in shape rounded or ovoid or pear-shaped, with finely granular protoplasm, and containing a central collection of pigment grains which often displayed Brownian movement. The flagella varied in number from one to four, were slender and delicate, and in length measured three to four times the breadth of the body. Rarely the flagella would become detached and move away as free-swimming cilia. This phenomenon was noticed by Laveran, who therefore thought that the cilia was the essential element of the parasite, and that the body was a cyst in which it was developed; but we have seen how rarely observers have noted these flagellated bodies, so that they may be regarded
1 to 12. Consecutive changes noticed in the form of a plasmodium, contained in a red blood corpuscle, during twenty minutes. (Marchiafava and Celli.)

13. A corpuscle containing two forms, one being pigmented. (M. and C.)

14. A motionless plasmodium issuing from a red corpuscle. (M. and C.)

15. A plasmodium containing granules of haemoglobin and black pigment. (M. and C.)

a to z. Progressive development of a pigmented body, in the apyrexial period up to final division and dispersion as the attack commences. (Golgi.)

A. Crescentic forms. (Golgi.)

A, B. Blood-vessel of the cortex of the brain. A. red corpuscles containing unpigmented plasmodia in process of division; one group already free. B. pigmented plasmodia in process of segmentation; one group free, with pigment granules still in the centre. Stained with aqueous solution of methyl blue. (Marchiafava and Celli.)
regarded as a rare manifestation and in no way an essential element in the diagnosis of malarial blood.

We may summarise then the results of Marchiafava and Celli's researches, in their own words; (note sur les études modernes, etc. Arch. Ital. de Biol. Tom. 18, p. 317) the principal characteristic forms being:

(a) Non-pigmented intra-corporeal amoeboid forms.
(b) Pigmented intra-corporeal amoeboid forms.
(c) Free pigmented forms, with or without mobile filaments.
(d) Semilunar pigmented forms.
(e) Pigmented forms with undulating outline.
(f) Pigmented forms in various stages of segmentation up to the formation of young bodies.
(g) Non-pigmented forms in process of segmentation (central capillaries).

"Considering their composition, their manifestations of life, the intimate connection between their effects and the pathology of malarial infection (dyscycthaemia, melanoemia, etc.) and finally their
their exclusive and constant presence in malarial blood, which indubitably transmits infection; it seems to us not unreasonable to regard them as parasitic organisms, and to call them malarial plasmodia or haemoplasmodia.”

(1856, pages 135)

Marchiafava and Celli, and E. Maurel found organisms, to all appearance identical, in the soil and air of malarious districts; indeed the latter observer professes to be able to differentiate, between a malarious soil and one that is harmless, by the presence or absence of these forms. (1856, p. 135)


The latest observations on this remarkable organism have been made by Surgeon J.

Yenton
Fenton Evans, M.B. Edin., of the Indian Medical Service, who examined a large number of malarial patients - European and Native - in the Field Hospitals at Mandalay in 1887-8 ( Brit. Med. J., April 15th, 1888), as he was frequently examining blood from patients under my care in the Native Hospital, I had ample opportunity of inspecting his preparations, and we agreed in identifying the bodies as the same as those described by Marchiavaco and Celli.

The relation of the various forms to the paroxysm, and their presence in the different types of malaria has not yet been fully worked out, but the following has been ascertained.

The ameboid and pigmented bodies occur both in chronic and acute cases, but are more especially characteristic of the latter. Marchiavaco and Celli note that, in acute cases and the intermittent of summer and autumn, the unpigmented forms occur, while in those of winter and spring (probably old cases re-excited by exposure)
exposure to cold) the pigmented forms were the most frequent.

Golgi was the first to note the relation of the segmented forms to the paroxysm, and he traces fully their development during the interval period between the attacks, from a small body gradually increasing to one that has absorbed the substance of the red corpuscle, and the division of the parent form and subsequent scattering of the young generation produced. Comeliman too has noted the occurrence of this form before the shivering fit, and its disappearance afterwards. It always occurs along with the ameboid bodies, being it is believed the mature form. The crescents are found in malarial cachexia often in great numbers, in which cases no ameboid forms occur; also in chronic cases, or those that have been under treatment for some time. The flagellate organisms are mostly seen in chronic cases, and Comeliman states that they are most readily found in blood drawn direct from the spleen.
The influence of quinine on the organism is very marked, indeed it has the same paralyzing action on them as on the protoplastic and unicellular forms described by Bing. This is well seen in cases showing numerous hyaline and pigmented bodies before the accession of the fever, for if quinine be given they disappear or become rare, and are always immobile.

Arsenic does not appear to affect the hyaline bodies, and, though it improves the general health, neither it nor quinine acts on the oocytic forms.

Of what nature then are these organisms? It is made evident that they are not of the nature of bacteria or micrococi, but rather related to the flagellate protozoa. It will serve to throw light on the subject if we study similar organisms known to exist in the blood of various animals in health and disease.

In 1843 Gruby (Compt. Rendus Nov. 1843) discovered an organism in frogs' blood which he named Trypanosoma sanguinis. This
organism was again discovered and described by Lankester in 1871 (Proc. Roy. Ir. Acad. Sci. XI p. 387) as a minute pyriform sac with a flagellum at one end and an undulating membrane at the other. There were also seen little albuminous bodies with sometimes attached filaments (Prepondium Panarium) which he regarded as the young stage of a sporozoan allied to Sacrocystis or Coccidium (Proc. Roy. Soc. VI p. 920). Mitrophanow in 1883 (Biologische Abhandl., XXI, III p. 33) found other organisms in the blood of the carp and the mud fish consisting of an elongated body with a delicate flagellum at the anterior extremity, and a spiral, or straight, undulating membrane arranged along the body. "In the same blood two other forms were observed, one without a membrane, but having two highly refractile spherules in the protoplasma, and another with neither membrane nor flagellum consisting of very granular protoplasma, with several refractile spherules and capable of

protruding
prominent processes like pseudopodia which he considers to be, in all probability, developmental forms. In these organisms he suggests the new genus, Haematomonas. (Jour. Roy. Micro. Soc. 1886 p. 920 and Fig. 195). In 1877 Surgeon-Major J. R. Lewis while investigating the so-called "spirillum fever" discovered, in the blood of Indian rats at Calcutta, a similar flagellated organism which he subsequently identified as the same as the parasite found, by veterinary-Surgeon Griffiths, in the blood horses, mules, and camels suffering from surra. (Report No. 239 Punjab Govt. Dept. 1880; Quart. Jour. Micro. Sci. 1879 and 1882). In 1886 Crookes briefly furnished an exhaustive report, on specimens of the surra parasite sent to him by Lewis, as well as on similar organisms found by him in the blood of European rats. (Jour. Roy. Micro. Soc. Dec. 1886). He came to the conclusion that the forms of Lewis, the surra parasite, and those found by himself in European rats were identical, morphologically, with each other and with the Haematomonas of Mitrophanous.
He made several observations on the life history of rat organisms, and found them highly polymorphic, and occurring in globose, angular, non-flagellated, biflagellate, semi-circular and disc forms. (Jou. Roy. Micro Soc. Vol. IX, p. 928 and fig. 198)

"In the Biologisches Centralblatt for 1885, Prof. Danialevsky of Charkeff makes an important contribution to the subject. He states that Trypanosoma, the well-known flagellate organism of frog blood is polymorphic, and occurs in an ameboid form, and also produces spores; and further he has found in the red blood corpuscles of birds a pigmented protozoic body which subsequently appears in the plasma as a pigmented flagellate organism. He suggests the identity of the pathogenic blood parasites of man with the haematoyxa of healthy animals, and infers specially to the similarity of the forms which he has found in birds, to certain of those described by savarau in malaria" (Brit. Med. Jour. p. 561, 1887)

Lastly Surgeon Fenton Evans J. M. S. has also
the same organisms in the blood of horses afflicted with surra, as he found in the malaria-stricken men in the Field Hospitals at Mandalay (Feb. 26th, 1903).

In these closely allied forms we can trace in a very complete way the life history of the malarial parasite, and realize the fact that the various forms found are simply stages in the development of a single organism.

No doubt the flagellate form is the adult condition, developed from the pigmented amoeboid bodies, but its exact geneesis is not known. The other forms can all be traced, probably as follows.

On the dispersal of the segmented bodies the new generation withdraw to some of the internal organs (spleen, liver?) and there attacking the young red corpuscles make their reappearance as the amoeboid hyaline bodies of Marchiafava and Celli (Golgi, p. 17); these subsequently take up pigment and develop into the segmented forms of Golgi or the crescentic bodies of Lauevan. Here
Here then we have the complete life-history of a flagellate protozoon of the order Flagellata-Parasitomata, and if Mitrophanow's genus (originally designed to include only the forms found in the carp and the mud fish) be enlarged so as to include all monads inhabiting the blood, then we have:

"Genus: Haematomonas;
Species: Haematomonas malariae.

Definition: Body plastic, ovoid or globose, with differentiation of protoplasm, which contains pigment grains; flagella, variable 1-4.

Highly polymorphous, occurring in (1) Amoeboid form.
(2) Crescent, encycted form.
(3) Sporocyst.
(4) Circular free pigmented bodies."

The question now naturally arises, are these organisms, so constantly found in the blood of malaria sickness patients, pathogenic, or do they merely find in the blood, altered by the action of malaria, conditions suitable for their development?
Although a complete demonstration and proof of their pathogenic nature cannot yet be given, nevertheless the evidence already collected points very strongly in that direction, as the following summary of the facts will show.

1. The presence of the organism in all cases of malaria, save where quinine has first been administered, or where probably a sufficient number of observations had not been made.

(Laurain, Oslor p. 561. Marchiafava and Celli, Son Infect. malarieme p. 302)

2. Their presence and multiplication in previously sequestrated, or inoculated with malarial blood, and the absence of all other micro-organisms from the injected blood.

(Gehard, and Marchiafava and Celli, Son Infect. mal., p. 304. Bonaccuolo, Studi sul l' Infect. malarieme p. 160.)

3. Their abundance in grave, and fewness in slight, forms of the disease. In cases of double quartan with alternating slight and severe attacks this is well seen.

(Galbi, p. p. 156 and 161. Marchiafava and Celli, Oslor p. 561)

4. The relation of the segmented forms to the
the onset of the attacks; and the "divinum 
precipit" seen in pernicious cases.

(See l' injection malarienne p. 290. Bolyi p. 157) 

5. The relation between the action of the para-
site on the red corpuscles, and the 
symptoms and pathology of malaria. 
(Anaemia malariae) (Kolleris studio e. p. 133)

6. The action of quinine, equally on 
the organism and on the disease. 


7. Their absence in healthy individuals 
living in malarious localities, so much 
so indeed as to be useful as a diagnostic 
(Oster p. 362; Marschinski u. Lelli. Sur l'Infect. malar. p. 302-3)

8. Their presence in the soil and air of 
malarious districts. 


The only links wanting in the chain of 
complete evidence are, firstly, though it 
has been proved that parasite-bearing blood 
transmits infection when injected into a 
healthy individual, yet no one has tried 
whether depriving the blood of its parasites 
would not at the same time remove from 
it its toxic properties. And secondly no 

one has as yet succeeded in obtaining a pure cultivation of the organisms, either from the blood or soil, so as to try injection of these alone.

Now though the evidence in favour of their pathogenic nature is overwhelmingly strong, yet we cannot say positively that the Haematomonas malariae is actually the cause of malaria. Yet still the idea that malaria is due to the action of a living organism capable of existing and multiplying under very different conditions of soil and climate and physical surroundings, is such an admirable working hypothesis, that the evidence against it would require to be strong indeed to induce anyone to abandon it, whose lot is cast in a malarious locality, and whose daily labour brings under his notice the fearful havoc wrought by the unrestricted development of malaria. The hypothesis of Professor Moss of Turin that the forms described by Laveran, Richard, Marchiafava and Celli, and Zelgi etc. are not parasites
parasites at all, but a mere evidence of a necrobiosis of the blood cells, need not detain us here, as it has been most ably refuted by Cattaneo and Monti. (De la formation des globules rouges etc. Arch. Ital. di Biol. June VIII, p. 252: & Alterzioni Degenerative des Corpuscles Rouges etc. Arch. Ital. di Biol. June IX, 1858.)

Let us now turn to the second division of our subject viz. —

II Is it possible to render a malarious locality healthy?

So many of the conditions of life of the malarial organism have already been described in the first part of this thesis, that a very brief summary must suffice in this place.

Tommasi-Credelli, who has had wonderful success in the reclamation of malarious tracts of land in the Roman Campagna, lays down as necessary for the growth of the organism the following conditions:

1. A temperature not lower than 68°F.
2. A moderate degree of permanent humidity.
3. The direct action of the oxygen of the air on all parts of the morsus.
The absence of any one of these three conditions is sufficient to arrest, or render impossible the development and multiplication of the ovum. (Passmore, vol. xxvii, 1881.) These observations correspond with the experience of the Italians, which goes to prove that:

1. Malaria occurs at high altitudes as well as in low lying districts; two-thirds of the malarial of Italy occurs on high ground. The surface may be dry but if there is subsoil water, and crevices or pores by which air can reach it, malaria will be produced.

2. Malaria ceases when the air cannot act directly on malarial soil. Full marshes are innocuous, so is ground covered by pavement or otherwise; but let the ground be broken up, and malaria reappears even after centuries.

3. A very moderate degree of humidity is sufficient; showers in the hot weather.

4. The production of malaria is suspended when the average summer temperature is low. Keeping these conditions in mind then, no
see in what directions to work to render a locality less malarious, and we aim at accomplishing this by means of thermic, hydraulic and atmospheric ameliorations.

Let us first look at nature's method of reclaiming lands.

Thermic amelioration is brought about every winter by the fall of temperature, or even in summer by a low average temperature. This however is liable to be interrupted by rise of temperature such as that produced by the blowing of a hot wind.

Hydraulic amelioration is often seen in the height of summer, when all the moisture in the soil has been drawn out of it by the heat; even a slight shower however is enough to destroy this and produce an outbreak.

Atmospheric amelioration is occasionally seen when a river overflows its banks and deposits a layer of alluvium on malarious lands, and also in the "earth felt" produced by the roots of grass.
Nature's methods are transient and uncertain at the best, but we see if human methods give more satisfactory results.

Amelioration may be attempted by eliminating one or more of the three factors, necessary for the development of malaria.

A thermal amelioration is of course impossible, for we cannot control the solar rays, nor reduce the temperature of the ground to $38^\circ$ Fahrenheit.

Hydraulic amelioration has been tried in many cases with marked success by means of drainage. Such were the principal means used by the Italic, Latino, Vallesian, and Romans, by which they rendered the Campania so healthy as to make it the favourite summer resort of the wealthy Romans during the last centuries of the empire; for it was lately discovered that they had constructed a very complete system of eburner drainage — often arranged in tiers — by which the subsoil was drained.
We may frequently assist this drying up of the soil by clearing away forests which prevent evaporation; and so get a twofold action, a draining away below and an evaporation from above. Lancisi taught that forests ought to be maintained and extended in malarious countries, as tending to intercept malaria from the marshes; but there is no doubt that forests often act injuriously by keeping the ground moist. Cruceli cites the case of the Cisterna township situated near the Pontine Marshes, and separated from them by a forest of trees. About thirty years ago these were cut down, and twenty years afterwards Cruceli was able to show that the health of the people had much improved.

A Commission, appointed by the Italian minister of agriculture in 1884, to inquire into the whole subject of the coexistence of woods and malaria, agreed with Cruceli that if the ground is malarious
the planting of wood will not improve it but rather the contrary, and that the great thing is good drainage. Absorbent plants have been tried, but with little success, though it is reported (Zimomo Cyclo. Vol. II p. 568) that Maury succeeded in combating the malignant fevers that flourished in the marshes surrounding the observatory at Washington, by planting sunflowers, which have an uncommonly great absorbing power. Eucalyptus has been tried in Italy both with the idea of an antiseptic action from the aroma of the leaves and a drying action from the great rapidity of its growth; but without good effect; and it is reported by Professor Riversidge of Sydney, that malarious fevers prevail in places covered by eucalyptus forest. Hydraulic amelioration is apt to be interrupted by showers and it is therefore advisable to combine with it if possible an atmospheric amelioration. Cundelić experiment at the Palazzo Salmi
has already been cited, and he also mentions that the new quarters in Rome (Quirinal and Esquiline) formerly subject to outbreaks of malaria, is now healthy since it has been covered with buildings and pavement.

At Hong Kong so much malarial fever attacked the men of certain barracks that the latter had to be given up. Now near these special barracks a great amount of levelling, earth-cutting and road-making was carried on. The soil was ferruginous clay and disinteg. rated granite. D'Odorico, who was called in, caused the nearly levelled ground to be covered with turf, and the scraped sides of the excavated hills to be protected by chunam. In a short time the neighbouring barracks again became healthy." (D'Odorico p. 47.)

The same rule has been always acted on when building the new barracks and hospitals in Upper Burma; a layer of bricks or cement being laid down under the buildings.
Cultivation with its careful ditching and draining, no doubt acts partly in the same way. Liske is supposed to have some effect in preventing the development of the process, for Klein and Cruveil report (Syd.Soc. Monograph 1888 p. 8) that “the experiments made by Longi and Terrig in 1873, and repeated by them on a large scale in successive years, during the works at the Colosseum, render it very probable that the addition of lime and its soluble salts to some malaria-producing soils diminishes or suspends this production.” By one or more of these methods there we can greatly improve malariaous localities; and what that means to the inhabitants can be fully appreciated only by those who have seen the wretched and miserable condition of a malaria-stricken race.

Let us now turn to the last division of our subject.

III Can means power of resistance to the malarial
Malarial poison be increased?

This question is of special importance to the soldiers on active service, for it is very evident that, while on the march, little can be done to improve the many camping grounds where he halts, perhaps only for a single night. But if it can be shown that he can carry with him an "antiperiodic native" which will protect him from malarious fevers, then indeed a very great boon will have been conferred both on himself and also on the Medical Department of the army, into whose hands he falls when stricken down with Ague.

One naturally turns first Ball to quinine, and we find that his phytotherapeutic nativity of that drug were first tried in the China war of 1860; but though it was thought to have done service, no definite experiments were made.

At Peshawar however, in 1866 during the autumnal months when fever is very rife, a trial of quinine was instituted. The different corps were divided into
wings: the men in one wing having 5 grains every evening, the men in another having none. From September 1st to November 30th, 1203 men took quinine with an admission into hospital of 10.22 per cent. for malarial fever; 1202 men did not have quinine, with an admission rate of 27.28 per cent. for fever. Here, the material, the place, the general conditions were the same, and hence this experiment in corpore vili is of much value. (Smeaton p.189)

In America, Van Buren and Hammond report in favour of the ration, and the general experience is that it is of value. But on the other hand the French in Algeria have not had good results. Sir Anthony Home reports in the Ashanti war that "he was unable to recognize any value resulting from the practice of giving a daily quinine ration". In the Malay war (1875-76) the Buffs were attacked by malarial fever one month after they had been regularly taking it. Here then though the evidence is certainly in favour of quinine as a prophylactic
yet as it is a costly drug, a paternal government is not inclined to allow experiments with it on a large scale.
The same objection cannot however be urged against arsenic which may be obtained for a mere trifle from any bazaar in India.
In 1856 Cruddel advocated its use by workmen employed in cultivating malarious soils, and in 1882 Dr. Ricchi, of the medical staff of Roman and South Italian Railway, administered to 465 workmen one milligramme of arsenic, increasing gradually to eight milligrammes daily. "Of these 338 were cured of fever which they had, or prevented from contracting them, in 43 cases the results were negative. Amongst the latter cases were those who did not take the medicine regularly, or only for a few days. In 44 cases the influence of the remedy was doubtful, but in these the medicine was alternated with other supposed prophylactics. Ricchi is convinced that if arsenic is not always
prophylactic against malarious infection, it renders the human organism less and less susceptible to the pernicious effects of malaria" (p. 156). When the arsenic has been administered some weeks before the malaria season sets in, and when its administration has been continued regularly throughout the season, the human organism best resists the attacks of fever. In some cases an absolute immunity, in others a relative immunity from malaria was attained. These latter cases are sometimes attacked by the fever, but even in the worst localities it never becomes pernicious, and they get over it with a little quinine. Last year for example Dr. Ricchi experimented on 78 individuals in the Borgo district where malaria is endemic. He divided them into two sections, one only 1/2 of which was subjected to the prophylactic treatment by means of arsenic. At the end of the febrile season it was found that while
while if the half consisting of those who had had no prophylactic treat
ment, many suffered severely from malaria, 36 of those who had been
under the course of arsenic remained entirely free from it, and the other
thrice had had slight attacks of which they cured themselves with a little
quinine without calling in the physician
at all." (Journ. No. 1864)
Surgeon Maj. H. Downie I.M.S. tried arsenic
and found it superior to quinine
as a prophylactic. Surgeon Duncan
I.M.S. also tried it in 1866; he put
four companies of the 23rd Punjab
Pioneers (all Musul Sikh) on arsenic, the
remaining companies not taking any.
His dose varied from 5 minims of
Fowler's solution twice daily, to 10 minims
thrice daily. Out of a total of 54 cases
of fever, 28 came from the companies
taking arsenic, and 26 from those
not doing so. When the large doses
10 minims was given, however (from 13th
November to December) the total cases
were
were ten, of which number only three were from the arsenic-eating company. In 1887 he again tried with another regiment, the 14th Sikhs, but his no result was obtained for out of 17 cases, 8 were from the arsenic eaters. (Punch 4, 1887)

In 1885 I was serving with the 14 Madras Pioneers at Bastan in the Gwal Valley, Southern Afghanistan; and nine miles distant at Kuchlak the 23rd Pioneers were encamped. Both regiments were apparently similarly situated, yet the Madras regiment experienced a violent outbreak of fever, while the Punjab Pioneers escaped with comparatively few cases. Surgeon Hamilton J.M.S. who was in charge of the latter regiment inclined to attribute their immunity partly to the fact that he had put them on a ration of arsenic; but possibly the situation of their camp may have been more healthy.

In July and August last (1888) I had an opportunity of trying arsenic on a troop of 4th Hyderabad Cavalry, stationed at
at Muttikke, a notoriously unhealthy outpost in the Ye-U district of Upper Burma; but here again the results were negative, partly I believe on account of the delay in procuring a supply of the drug, owing to difficulties of communication in an undeveloped and disturbed country. Still from the very strong evidence of the Italian observers, and the success of Downie in India, I certainly believe that in arsenic we have a great prophylactic remedy of universal applicability and much value, well deserving a further trial. Its very beneficial action on the red corpuscles in cases of pernicious anaemia, and the similar results obtained in malarial cachexia, would encourage me to hope that a prophylactic for malaria has at last been discovered. Various Italian physicians have lately loudly lauded a decoction of fresh lemons as a prophylactic for malaria...
and no lemons or lines are always to be found in abundance in all malarious countries, this is worth while to remember.

Tincture of Eucalyptus, Iodine and Alkaline Salicylates have also been tried, but without success.

In these recent researches into the origin and prophylaxis of malaria, we have certainly every encouragement to persevere in our fight with this most widespread of all pestilences, and to hope for greater success in the future, than has rewarded our efforts in the past.

W. Barcroft, M.D.
Surgeon J.M.S.
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