

Chapter 5

The Perfidious Mosquito

At the midpoint of the century, the disease with the highest incidence in the world was malaria. Every year, malaria was thought to strike 350 million human beings and cause one in every 100 deaths.

Most of both deaths and non-lethal bouts of fever were among children: those who lived in places where malaria was endemic and survived their early contests with it developed some degree of immunity. Even so, they stayed vulnerable to the coming and going of the parasite in their bloodstream, and spent their lives sporadically impaired by the severe headache, chills and sweats; the swollen spleen and anaemia; and the deep lassitude malaria induced. For pregnant women, it was a special threat since it could cause the loss of the child in their womb.

The malaria parasite takes two common forms: *vivax*, which debilitates and causes great sickness; and *falciparum*, fulminating and more often deadly. Malaria can be bewildering in its speed of devastation, especially among people not previously exposed. During the second World War, malaria hospitalized 378,000 US soldiers in the Far East, and was rated by General MacArthur as an enemy as dangerous as any Japanese force. In Egypt, *anopheles gambiae*, the most virulent malaria-carrying mosquito, appeared from Sudan at the height of military activity in the western desert region, and the parasites it brought killed 180,000 people before the carrier was wiped out.

Malaria was capable of depopulation. It had such serious implications for economic productivity that many malarious countries took it more seriously as a public health problem than any other.

The trick of malaria's transmission was discovered just before the turn of the century. The female of a blood-sucking *anopheles* mosquito species ingested the parasite while feeding on an infected person, gave it a home in her body for a part of its growth cycle, and then deposited it during another 'meal' into the bloodstream of someone else. Before the discovery of the man-insect-man transmission cycle, the only antidote was a therapy: quinine. After it, prevention was possible. Instead of killing the disease in the victim's bloodstream, it could also be killed in the mosquito.

Techniques for the mosquito's mass elimination were pioneered by William Gorgas, a US Army physician who led a famous battle against

yellow fever and malaria in the Panama Canal zone, making possible the Canal's construction. General Gorgas had many inheritors in both North and South America. They drained swampy land, larvicided standing water with copper-arsenic dust, and introduced larva-eating minnows into ponds. The armoury against the mosquito steadily grew, not only in the Americas but also in the malarious parts of Europe and in the colonial possessions of Britain and France, along with experience in the management of insect-borne disease control. The problem was that everything in the armoury was laborious and expensive.

Then came DDT. Dichlorodiphenyltrichloroethane was synthesized in 1874, but it took until 1939 for its lethal effect on insect life to be appreciated. Today, the reputation of DDT has been tarnished. But when it was first used during the second World War for public-health purposes against typhus and malaria, the way it stayed lethal to insects for months after being dusted into clothes or sprayed onto surfaces was seen as miraculous. By 1943, the compound was in mass production and its future in both public health and agriculture seemed limitless.

The first demonstration that DDT spraying, house by house, could dramatically reduce malaria was carried out near Naples in 1944 by two long-time warriors against insect-borne disease: Drs Fred Soper and Paul Russell from the Rockefeller Foundation. Their success prompted Dr Alberto Missiroli, Director of the national antimalaria service, to try and eradicate malaria from the Italian peninsula; this was achieved within five years. It also led to an effort to banish both mosquito and disease from Sardinia, a campaign whose merits Soper and Russell sold to Sam Keeny, then heading UNRRA in Italy. The campaign, using UNRRA-supplied DDT, did eliminate malaria; it did not eliminate the mosquito. Other DDT spraying campaigns followed in Europe and the Mediterranean, initially supplied by UNRRA, later by Unicef.

Spraying the inside walls of people's homes with insecticide was a well-established technique of malaria control. By the 1940s, it was regarded as preferable to larviciding since it specifically singled out those mosquitoes which were causing the problem. It was based on certain rules of *anopheles* behaviour. After a mosquito had taken her blood meal, she found it awkward to fly and landed on a surface nearby to help her digestion. Since she pursued her quarry at night, this was often the wall of the room in which the victim was sleeping. If that surface was toxic, the mosquito would die before the parasite could mature.

Soper had used this technique with deadly effect against *anopheles gambiae* in both North-East Brazil in 1939–40, and in Egypt during 1944–45. The weapon then had been insecticide made from the pyrethrum daisy.

The reason that DDT opened up such dizzying new vistas in public health was that it only had to be sprayed on a surface once or twice a year, enormously reducing manpower and insecticide requirements. Regular

DDT spraying of all households in a malarious area therefore became an affordable proposition and quickly eclipsed other antimalaria strategies.

Unicef's first assistance to countries trying to bring malaria under control went to various countries in Europe, including Hungary, Poland, Yugoslavia. Missiroli, the malaria victor of Italy, advised as to methods. When WHO came into being in 1948, the attack on malaria was cited as one of its top priorities. WHO, in the usual relationship between the two organizations, then became the technical adviser to national campaigns seeking international help, with Unicef as supplier—in this case, DDT and spraying equipment. As both organizations became more closely involved with health problems in the underdeveloped world, malaria control projects quickly expanded and DDT and spray equipment were in hot demand. By 1953, Unicef was spending around \$6 million a year on providing enough DDT to protect 13.5 million people in thirty countries and helping set up two factories for local DDT production in the Indian subcontinent.

The incidence of malaria—and, as a consequence, the disease and death rate generally—dropped dramatically once spraying began. In Ceylon, where a national control programme began in 1945, the number of cases dropped from the millions to the thousands, and then to the hundreds, in a few years. In Mauritius, the number of deaths ascribed to malaria in 1948 was 1500; seven years later, it was three, and the infant mortality rate dropped from 186 to sixty-seven per thousand. Unicef, involved in more modest programmes, could also cite impressive results: in Thailand, experimental spraying for one year in a malarious area reduced new cases among infants to zero, and the number of children with malaria parasites in their blood by eighty per cent. For economic planners, the savings were equally impressive. In one area of the Himalayan foothills, food production rose by fifty per cent as a result of Unicef-assisted spraying. In El Salvador, the cost of the insecticide, sprayers, spraymen, vehicles, and campaign management came to around fifty cents per person protected per year—a great deal less than the cost of land unused, crops unplanted, and people unwell. From 1951, the US Government began to invest large amounts in malaria control worldwide. Nationally and internationally, DDT spraying was a mass-campaign hit.

The euphoria was punctured in the early 1950s. Certain species of *anopheles* mosquito were becoming resistant to DDT. In Greece, a country where DDT spraying had been going on for several years, it was no longer a certain weapon against the three critical mosquitoes. An Indonesian species had developed resistance; so had two African and two American. The prospect that the *anopheles* could defeat DDT's effect by biological adaptation seemed to spell disaster to malaria control. Within a few short years, it was possible not only that all the recent progress would be undone, but also that malaria carried by the super-mosquito would re-appear in areas from which it had long since departed and cause unbelievable havoc.

Alarmed by this grimmest of prospects, the most prestigious combatants of insect-borne disease proposed a decisive strategy: a short, sharp stroke not merely to bring malaria under control, but to end transmission and eliminate the disease for good.

With the enemy daily increasing its defensive power against DDT, mere control was self-defeating; only eradication would do. Malaria was different from the other diseases currently under attack: the mosquito had imposed a deadline for achieving results. It took six years for the *anopheles* to develop resistance to DDT. Therefore, the choice was between indefinite malaria and indefinite control; and eradication within the next six years. At least, that was the choice presented in 1955 by Fred Soper, Paul Russell, E. J. Pampana, chief of WHO's malaria section, and veterans of other campaigns in Europe, Asia and Latin America. Soper, in particular, presented his case with great conviction; at this stage in the history of public health, there was no-one who knew more than he about what it took to eliminate malaria's vector.

Fred Lowe Soper came from Kansas and spent much of his career fighting mosquitoes in Brazil. He was originally sent there by the Rockefeller Foundation to attack hookworm, and in time gained a reputation for masterminding a brilliant and conclusive campaign against yellow fever and its vector, *aedes aegypti*; and for wiping out, in North-East Brazil and in Egypt, the lethal malarial interloper from tropical Africa, *anopheles gambiae*.

Soper was a forceful personality whose style of leadership was driving, zealous, and brooked no interference. He was one of the great names in disease warfare, a spiritual successor to Gorgas of the Panama Canal, and by the 1950s was already something of a legend.

In 1947, as the candidate of US Surgeon-General Dr Thomas Parran, Fred Soper became the Director of the Pan American Sanitary Bureau in Washington, the international public-health organization for the Americas. In 1949 the PASB also became the regional bureau of WHO, and was later renamed the Pan American Health Organization (PAHO). Soper, having given a lifetime of service to the control of disease in the Americas, fought hard to preserve for the PASB an independence of action for its activities in the hemisphere. During his twelve-year directorship, he considerably expanded the budget and size of its programme, giving much weight to the eradication of communicable disease and, in the case of yellow fever, to the eradication of *aedes aegypti*, its vector.

While the experience of Sardinia had proved that it was difficult, if not impossible, to eradicate a malarial mosquito from its indigenous habitat, it had also proved that it was possible to vanquish the plasmodium itself—the parasite. All Fred Soper required to commit himself to the universally-

desirable goal of the eradication of a specific disease was proof of technical feasibility. Operational feasibility, in his view and according to his example, could be managed; it only needed full jurisdiction, by which he meant full authority uncluttered by bureaucratic red tape and backed at the highest political level; adequate financial resources; and meticulous administration.

In October 1954, the fourteenth Pan American Conference meeting in Santiago, taking its cue from Soper and from Pampana of WHO, instructed the PASB to do everything in its power to eradicate malaria in the Americas. Belief in the possibility was fortified by the experience of Venezuela, where a national eradication campaign led by Dr Arnoldo Galbadon, another malaria maestro, was closing in successfully on its goal.

Soper had been pushing for continental eradication since 1950; but in the past few years, the early success of DDT spraying in malarious areas had lulled ministries of health into a sense of security. Just when the DDT-resistant *anopheles* mosquito was about to strike back, they had reduced their budgets for malaria control and relaxed their efforts. This was common to almost all disease-control campaigns: when a type of illness which had been common disappeared from a locality, it was difficult to persuade both inhabitants and health administrators that a campaign's momentum should be maintained. Determined to swing the pendulum back, Soper had become a forceful salesman for an invigorated international malaria-action plan in the hemisphere, for which he had full WHO support.

On 15 March 1955, Soper addressed Unicef's Executive Board in New York. His belief that the threat of DDT-resistance made it imperative to declare a regional countdown against malaria carried great conviction. Since the 1954 Conference in Santiago, American ministries of health were committed in principle; but to carry out national campaigns they needed international help. The PASB could offer technical advice on the disease and its vectors and on how to run campaigns against both, but it could offer much less help with the hardware: DDT, spraying equipment, and vehicles. Hence the appeal to Unicef's Executive Board. Here was a unique opportunity, Soper suggested. A permanent solution to a disease which affected fifty million people, most of them children, could be achieved by a small investment of capital over a short period.

Soper's belief that malaria eradication was technically feasible was based not on the idea of destroying every last *anopheles* mosquito—which had failed in Sardinia—but the mathematics favouring the extinction of the parasite. If the mosquito and parasite were kept apart, parasites could not be taken from, nor deposited in, the human bloodstream. If existing parasites waited in vain for an *anopheles* bite to take them onto the next stage of evolution, their life cycles could not progress. The parasite would die out and the bite of the *anopheles* would eventually become harmless. Since a person's bloodstream divested itself of the parasite after three

years, malaria would disappear from an infected area during this time unless reintroduced from elsewhere.

Because of the uncontrollable to-ings and fro-ings of mosquitoes and human beings across boundaries, eradication in a country, let alone a continent, was only feasible if campaigns were co-ordinated between contiguous malarious areas simultaneously. This was Soper's boldest leap: from a local campaign in a geographically self-contained area, such as the island of Sardinia or the Italian peninsula, to a rather larger land mass; not just a country or even a continent, but a hemisphere. Once a malarious area had been sprayed into harmlessness, the most solid defence had to be erected against the possibility of the parasite in either of its vectors—man or mosquito—re-entering.

Soper's plea for Unicef support was strongly backed by its own Director for the Americas, Robert Davée. Davée proposed that Unicef spend \$3 million a year for four years on malaria eradication in the region, mostly in Mexico where the problem was worst. This represented a very large allocation for one particular type of programme, but he believed it was worthwhile.

Many delegates did not agree. They were by no means convinced that Unicef should throw such a disproportionate amount of its scarce resources—about a quarter of the total—into one continental programme. Not only might other projects in the Americas suffer, but also there would be less money available for other parts of the world.

Some felt that Unicef was forgetting its mandate. This campaign would certainly help children; but were its benefits specific enough to justify the volume of support? Others were sceptical that the costs and technical aspects had been fully appreciated. They wanted more answers before committing Unicef to such an ambitious venture, and asked that the WHO/Unicef joint health-policy committee consider the idea and make recommendations.

Senior delegates from the two organizations' governing bodies met in New York on 6 May 1955 for the health-policy committee meeting. Some of the world's leading experts on malaria took part. Their support for replacing the goal of malaria control with that of eradication was persuasive. The committee discussed the implications, and unanimously signalled a green light not just for the Americas, but also for malaria eradication everywhere.

The arguments pushing in this direction were partly scientific and partly emotional. The last five years had seen spectacular successes in breaking transmission and bringing malaria under control. It had been possible to achieve what ten years ago would have been dismissed as a fantasy: to *protect from malaria 300 million people, or half the world's total then estimated to be living in malarious areas*. The number of malaria cases had dropped globally by at least one-third.

It did not seem over-optimistic to imagine that an all-out effort could

complete the job within another five years or so, especially as more of the same would produce diminishing returns as DDT resistance grew. Only in Africa south of the Sahara, where the disease was endemic but where spraying had not yet shown the same results, was eradication recognized to be impracticable at present.

The experts recommended a 'revolutionary' approach, which was essentially that developed by Soper. Malaria eradication should consist of an 'attack' phase, and a 'consolidation' phase. 'Attack' would last no longer than four years: one year in which to stop transmission, and three years for the parasite to disappear from the local bloodstream. At this point, consolidation would take over: a system of surveillance would make sure that every time a case of malaria occurred, measures were taken to treat it and stop the disease spreading. Although the attack phase would be expensive, there were cost advantages in the strategy: surveillance would be cheaper than attack since it would merely treat a few cases and keep an eye on danger zones. After another four years, surveillance would be wound down. Allowing for preparatory time and inevitable delays, the two phases would last around ten years, which was therefore the period for which a national malaria service would be needed. After that, malaria would be a rarity and could be treated by 'maintenance': the ordinary health care network.

Reaching the maintenance phase did require an initial all-out effort and investment. Both national governments (on whom most of the burden would fall) and international organizations would have to pledge themselves to commit the financial resources necessary to carry the campaign through to the end. Once started, any going back in any country would threaten the potential for success in a neighbouring one. The absolute nature of the moral obligation and the long-term financial commitment to malaria eradication made this mass campaign different from any other, including its own precursor, malaria control: DDT resistance and the deadline it imposed appeared to constitute such a threat that there seemed no alternative but to accept their terms.

First signalled in 1954 not only by the Pan American Sanitary Conference, but also from a regional WHO conference in Asia, international momentum was gathering behind the call for malaria eradication. When the World Health Assembly met in Mexico shortly after the joint WHO/Unicef committee meeting, it took its cue on malaria from their discussions. One of the most famous resolutions in WHO history was passed, urging governments in malarious regions to abandon malaria control for malaria eradication and to speedily re-design their programmes accordingly. Those who felt sceptical found their voices stilled by the fervour of the moment. The entire world health community was bent on committing itself to an all-out crusade.

Few of the delegates realized quite how much they were demanding of

themselves and others. As Fred Soper liked to observe, 'perfection is the minimum permissible standard' for a successful eradication campaign. In the social and economic circumstances of most malarious parts of the world, perfection was a very tall order.

Now that the green light had been given, Unicef enthusiastically advised its staff around the world of the new emphasis in malaria assistance, and pressed them to make its case to governments. In Africa, where no-one as yet had managed to interrupt malaria's transmission, control could still be supported if its purpose was to act purely as an interim step.

Elsewhere, existing malaria efforts should be re-planned as quickly as possible to match the new 'attack' and 'consolidation' format. Before requesting further supplies of insecticide or sprayers from Unicef, governments should show their commitment to eradication by setting up a national malaria service and by pledging financial support to complete the programme to the bitter end. They would also have to pass the necessary laws; malaria had to become a compulsorily notifiable disease and sprayers have the legal right of entry to people's houses.

Of all disease campaigns conceived as something done to a passive population, this feature made those which attacked insect-borne disease the most oblivious to people's attitudes. A leprosy lesion or a yaws sore could be hidden; it was more difficult to hide a house. They were also the most intrusive; people had no choice about whether or not they co-operated.

The regional eradication programme in the Americas was now assured of Unicef's whole-hearted support. First in the field was Mexico, where nineteen million people lived in malarious areas. The Mexican Government intended to mount a four-year mass eradication campaign, and asked Unicef to meet the \$8 million costs of insecticides, transport, and sprayers—a request which the earlier hesitations had put on hold. In September 1955, fortified by the WHO resolution, the Unicef Board voted a first instalment of \$2.4 million for Mexico's antimalaria drive, the largest amount of money allocated to a single project in Unicef's nine-year history.

A campaign to spray, one-by-one, on a regular basis over three million houses required herculean feats of organization. The Mexican authorities were already deep into plans for their attack phase, having set up a national malaria eradication commission to run the autonomous operation under the health authorities which Soper and other veterans regarded as critical to success. Under its guidance, surveys were being carried out on the *anopheles* species and their guests, the plasmodia, and their various living, reproductive, and dietary habits. Hospitals, health centres, and private medical practitioners in malarious areas had been instructed to report every case of fever. Mobile teams of sprayers were in training.

Houses were being numbered and mapped, and itineraries prepared. The army was in charge of logistics, adding real military presence to a campaign characterized by the vocabulary of war.

The campaign was launched on 7 September 1956 in an atmosphere of high excitement and with every visible sign of political support. President Adolfo Ruiz Cortines reviewed his national malaria combat troops at a grand military parade on the central avenue in Mexico City. In the line-up there were 300 senior officers, 1650 spraymen, and a column of 600 campaign vehicles, donated by Unicef, painted bright yellow and stamped with the malaria-campaign emblem. Soper was present, as were Maurice Pate and Robert Davée. Nationwide radio broadcast the presidential proclamation. Newspapers carried banner headlines. Cinemas screened a film about the campaign, which opened with tanks careering over a hill to the sound of martial music.

The 'attack' was planned to last three years. The 200 mobile malaria squads visited areas where malaria was a year-round problem twice a year. Where it was only a problem during the rainy season and the months following, they visited once a year, timing their spraying to precede the mosquitoes' busiest periods of feeding on human blood. A precise schedule covering three million houses, taking into account weather and road conditions as well as all local variations of mosquito and human behaviour, would be difficult to plan anywhere in the world; but where people were not living in a close-knit and organized society it was more than difficult.

Some of the villages up in the Sierras were so remote that they could only be reached by packhorse. The 'mounted cavalry' of the campaign—khaki-clad spraymen in paratroop boots and helmets—forded rivers and climbed paths carrying malaria flags. As they sprayed each house, often over the objections of bewildered householders, they attached a sign with the date. In towns and villages and jungle clearings, they put up posters to appeal for co-operation. In schools, meeting-places, and churches, the campaign was explained. Vigilance against the mosquito was endlessly preached.

The attack phase of the Mexican campaign encountered operational problems typical of many campaigns. Map-making and census-taking revealed early on that the number of households in malarious areas had been under-estimated by a considerable margin: 500,000 or one-sixth. In 1958, heavy rains caused flooding and spread malaria to parts of the country previously spared, once again increasing the numbers of houses to be sprayed. These setbacks lengthened the period of attack, and substantially increased the costs of the campaign, causing considerable headaches to both the Mexican authorities and their international partners. In other ways the attack moved ahead satisfactorily; the teams of spraymen managed to beat their target of ten households a day; the supply chain of insecticide and equipment held up; logistics and transport ran smoothly.

By 1959, the epidemiologists could report that the most prevalent of the malaria parasites—*falciparum*—had disappeared for more than eighteen months in areas inhabited by more than half the population at risk.

These results were extremely impressive. They were also worrying. In the other malarious half of Mexico—in the warmer, more humid and low-lying coastal areas where the mosquito was most in its element—vector and plasmodium had defeated the attack. The same disconcerting news was beginning to filter in from a number of other countries.

Malaria eradication had been predicated on the theory that one or at most two years of blanket spraying would be enough to prevent more than a completely insignificant number of new malaria cases developing. The rest of the attack phase was to keep mosquitoes away until the parasite had left the local bloodstream. In many places, transmission had been broken in the time set; in others, after spraying for eighteen months or longer, it had not. One alternative was to change the insecticide: in some places this was tried and worked. In others the problem was not so clear-cut. Was it the lack of organizational perfection? Or was there something wrong with the underlying theory? At this stage, most people were still convinced that, with the right backing, financial resources, trained personnel, administrative perfection, and warlike vocabulary, the malaria parasite would have to succumb.

As malaria eradication campaigns progressed in countries all over the world, they evolved on the basis of information thrown up by their own activities, like other mass disease campaigns. This was information that was previously unavailable for many of the areas into which the attempt at universality was carrying health services and medical personnel for the very first time. Also for the first time, this information was being systematically pooled through the international organizations involved. It was a phenomenon of all mass campaigns that they discovered a much larger spread of their disease than expected, and that its epidemiology always turned out to be much more complex than any map with coloured, hatched, and shaded patches could ever imply.

In 1959, just before the five-year mark and the moment at which the attack phase of many campaigns should be closing down, if everything was proceeding according to the symmetry of maps and theories, WHO's malaria experts produced an exhaustive technical appraisal of what the campaigns had accomplished.

In a handful of countries—most of them in Europe or the Caribbean—eradication had been achieved; in many others it had been 'commenced' or was 'in preparation'. Five years before, 600 million people had been thought to be living in malarious areas. Now the figure was amended to 771 million, of whom 516 million were living in areas where attack was

underway. A few years before, this definition would have been: 'protected from malaria', indicating tremendous progress. But because more than three years had passed—and three years had a witching connotation in malaria eradication—the discovery that 516 million people were living in the attack phase and that only sixty-four million had progressed to the consolidation phase sounded rather less encouraging.

The upwards revision of numbers meant that attack would have to continue for longer; the short, sharp, spraying phase was turning out, in a way sadly familiar to disease campaigners, to be neither so short nor so sharp as expected. The effect of turning malaria control into malaria eradication had become psychologically hard to handle. The veterans of insect-borne attack now fighting what, for them, was the world war of all time tended to remain optimistic. To men like Soper, setbacks were only to be expected and would be overcome. But their upbeat tone about campaign refinements were beginning to jostle with dissonant voices.

Problems were far from confined to the increase in numbers that surveys and spraying operations had thrown up. Each review of the campaigns recited the same litany of organizational defects. Some governments had embarked on the attack phase with more enthusiasm than appreciation of what was involved for parts of the country where censuses and maps were nonexistent. Malaria services lacked both the administrative calibre and the autonomy regarded as vital; many were understaffed, underskilled, and underpaid.

The analyses of many campaigns persistently upbraided governments for being 'unwilling or unable' to devote sufficient financial resources, and for failing to pass the necessary legislation—or at least to put it firmly into effect. Emphasis was mostly placed on organizational and financial shortcomings in the early analyses. Some recognition was also given to the 'technical' and 'social' problems posed by the behaviour of the creatures involved—man, mosquito, and plasmodium—whose respective contrariness had been greatly underestimated. Mosquitoes did not always ingest blood at the prescribed place or time or alight on walls having done so. Human beings did not all spend their evenings and nights indoors; some were nomadic and moved backwards and forwards across huge distances, taking their houses, their animals, and their plasmodia with them. Again, the analyzers chided those in charge: they had not carried out a geographical survey; they had started their campaigns with far less than the necessary epidemiological and entomological information at their fingertips.

The standard list of operational shortcomings spoke volumes as much about the over-optimistic expectations of those who drew it up as it did about the campaigns themselves. The fact was that many of the malaria men had writ large a campaign in Italy, Sardinia, the plantations of Malaya and the US army camps of the Pacific, but they had simply not bargained for conditions on the ground symptomatic of gross under-

development, covering huge areas and large, remote, spread-out populations whose ways of life, like those of their zoological companions, were not fully understood.

To level these kinds of criticisms against many of the countries in question was tantamount to criticizing them for being malarious. If their public-health authorities had been able to reach such administrative perfection and budgetary reliability, lacking only technical advice and DDT, their populations would probably not have been suffering from such a massive disease problem in the first place. Some very large countries—India, for example—understood what they were taking on when they ‘converted’ from malaria control to malaria eradication, and did so only when they were ready. In Asia, anyway, the organizational problems were not so deeply confounded by serious technical problems—mosquito and plasmodium perversity—as they were in Africa and Central America. For a long time, however, it was difficult to disentangle one set of problems from another.

Once governments and their various international helpers had committed themselves and their resources down the line, and in the absence of any conclusive evidence that anything had happened other than a postponement of the goal, it was natural to hope that an extension of the effort would resolve the problems. Time had by no means yet run out; in many parts of the world *anopheles* had not yet developed unmanageable resistance. WHO’s 1959 appraisal rang with conviction that the goal was as attainable as ever, that the strategy was sound, that the principles remained intact, and that a more refined understanding of the complexities involved only proved that no slackening of effort was justified. In this report Soper, who was by then on the verge of retirement from PAHO, had a considerable hand; another irrepressibly-optimistic Unicef colleague, Sam Keeny, was on his team. But Unicef as a whole was beginning to balk; reaching the end of the attack phase, let alone the ultimate goal, was obviously going to entail much greater expense over a much more extended time frame than was originally thought.

In 1955, when the drive for eradication began, Unicef had agreed to provide weaponry and transport for the attack phase—DDT and other imported supplies—primarily in the Americas and the eastern Mediterranean. The US Government, through the International Co-operative Administration (ICA), the precursor to USAID, had become the largest international donor to malaria eradication, providing the external supplies needed for the programmes in the larger programmes of Asia—India, Pakistan, Indonesia—and for Brazil. WHO offered technical advice, co-ordination of the global effort, and evaluation; and PAHO offered technical advice and regional co-ordination in the Americas. The costs to Unicef of becoming the quartermaster for its share of worldwide spraying campaigns had been calculated on the basis of existing malaria-control projects, then

averaging twelve cents per head of population protected per year. The target population in the countries destined for Unicef assistance was estimated at forty million; the costs were expected to be \$5 million a year over five years.

Within a year these estimates had risen substantially. In 1956, the Unicef Board accepted that they had been too conservative, but imposed a ceiling for the rest of the decade: not more than \$10 million could be spent on attacking mosquitoes in any one year. The Board had not been very enthusiastic that almost half of Unicef's total programme budget might be absorbed on campaigning against one disease, but the temporary high cost had been accepted because it was seen as a worthwhile long-term investment in children's health. By 1960, it was assumed, most attack phases would be over and aid would phase out: it had not been imagined that Unicef's help would be needed during the consolidation phase.

On the verge of the new decade, however, a long-term investment for a few years only was becoming an abnormally high recurrent cost: \$8 million a year. In the disused language of malaria control, the numbers of mothers and children freed from the misery of malaria—the homes of over thirty million people were sprayed in 1959—the campaign's results were exemplary; but the only recognized gauge of success was progress towards eradication.

For all the reasons outlined in WHO's report, the attack phase was still going on and looked as though it would do so for some time to come. Instead of peaking in 1957–58 and then declining, demands on Unicef resources were likely to rise unless an effort was made to check them. Unicef did not question WHO's view of eradication's technical feasibility, nor the likelihood of its ultimate achievement. But other considerations intruded, many of them raised back in 1955 before the eradication policy had been adopted. Unicef, the organization which existed to help promote 'child health purposes generally' could not be indefinitely distracted by malaria eradication. Whatever the merits of trying to reach the goal, the time had come for Unicef to establish a timetable for the reduction of its annual expenditures on this one disease in such a way as would be least damaging to promising projects and to its relations with governments and other international organizations.

In 1959, the Unicef Executive Board took a careful look at the information available, and attached stringent conditions to Unicef's future aid for malaria eradication.

No new projects would be helped except in very exceptional circumstances. The renewal of assistance for existing programmes would depend on their being able to demonstrate that their operations were technically, financially and administratively sound, and that the prospects of eventual eradication appeared good. If it was necessary to extend the attack phase for a year or two beyond the original timetable, support would probably

continue; but if malaria transmission had not been halted by the fourth year of spraying every house in a malarious area, spraying should cease and the entire basis of the campaign be re-considered.

Assistance to malaria control would be limited to pilot schemes and preliminary surveys; there must be reason to think that these 'pre-eradication' projects would lead to full-scale eradication in due course, although Unicef in no way committed itself to supporting such projects when they decided to do so. Under these terms, Unicef hoped to lower its assistance to malaria campaigns from \$9.5 million in 1960 to around \$3 million in 1964.

In one respect alone, the policy laid down in 1959 was more lenient than before: some limited assistance could be given to consolidation, including supplies of drugs and of insecticide needed to stamp out any remaining 'foci' of disease. By this stage, ideas of what consolidation should constitute, and what resources were required for it to work, had undergone a transformation. This was one more way in which the strategy for achieving malaria eradication had evolved. Ultimately, it was the most significant evolution of all.

The consolidation phase in malaria eradication was the phase at which spraying in a given area could cease when the number of people with the parasite still in their bloodstream had gone down to one in every 2000. The only way to find out when this magic moment was reached was by an effective surveillance system, a system which every national malaria eradication service was expected to put into place within two or three years of starting the attack.

At the beginning of the eradication drive, when the spraygun had seemed invincible, surveillance had not received much attention; everyone had concentrated on the drama and difficulties of attack. As attack began to yield less-than-perfect results in certain countries and areas, surveillance turned out to be a much more critical indicator of progress than any house count or spray schedule, and the importance attached to it began to grow. The ultimate test of any campaign was the number of plasmodia in the local bloodstream; and if there were still a fair number present after attack had been going on for a while, the results of surveillance were needed to help redesign the battle formation so that its pattern would have the desired effect.

Effective surveillance had to be based on the systematic collection and analysis of blood smears from malarious areas—not an easy proposition in places where there were few doctors, health centres or laboratories. The search for plasmodia in most of the countries was too large and expensive a task to be carried out by the full-time staff of the malaria service.

In some countries a familiar solution was employed: lay people were

invited to volunteer as reporting agents. In Mexico, these were known as *notificantes*, and over 30,000 from many walks of life were enrolled; school teachers and community leaders, as well as pharmacists, laboratory technicians and health staff in hospitals and clinics took part. The national malaria staff trained the volunteers in how to take blood smears and prepare slides, and gave them supplies of malaria drugs. Villagers and townspeople with symptoms of fever sought out their local *notificante*, gave a blood smear, and received treatment in return. Staff from the Malaria Commission visited regularly to give supervision and investigate the cases' origins. With certain modifications, this pattern of surveillance was used in countries all over Latin America.

While the system worked adequately in parts of the world with a relatively high degree of social organization and where the national malaria service could provide effective supervision, in most places the use of volunteers was not sufficiently reliable for watertight surveillance. The reporting of fever cases, the taking of blood-slides, their transport to the laboratory, their analysis, the follow-up of positive cases back in the village, required just the same degree of military precision as the attack phase. Surveillance operations were just as complex as spraying, but with less of their excitement or dramatic results.

Instead of battalions of combat troops to send out on a mosquito and disease destruction mission, there was an interminable pile of blood slides—it had to represent between three and ten per cent of the population in the malarious area—to collect and analyze. Hunting down and despatching the handful of remaining malaria plasmodia was unexpectedly turning out to be just as expensive as preventing the first thousands and tens of thousands of fever cases. Chemotherapy, a weapon against malaria which had not originally been expected to play any major role in eradication, was now hauled up from reserve. Not only did patients who had endured the invasions of the spraying teams without effective result need to be treated; but if the plasmodium could not be definitively killed off inside the mosquito, killing it also in the human bloodstream was the second line of attack. In some places where attack had not produced the expected results, spraymen were given supplies of malaria drugs to give out to household members as a preventive dose.

Gradually, as it became clear that the post-attack consolidation phase played an essential part in reaching the point of definite and certifiable eradication in a given area, it also became clear that the presence of a static and permanent network of health services, however rudimentary, was a pre-condition of eradication. In accordance with the unwritten laws of public health, the most malarious areas were by definition those where such health networks were skeletal or non-existent.

Advancing the basic health-service network into the countryside alongside the malaria spray squads therefore became a vital adjunct to a

successful campaign. In some of the countries of Asia—India and Ceylon, for example—this realization of the symbiotic relationship between the spearhead attack and the regular health-security forces prompted the faster growth of the latter. In most of Africa, and in larger or smaller parts of other countries, the installation of such networks was years, even a generation, away. Sponsors of malaria eradication were therefore forced to recognize that there were certain countries where eradication simply could not happen within the foreseeable future; and others where malaria could be banished from large areas, but where eradication from the entire country would remain elusive.

By 1961, Unicef's expenditure on malaria eradication had declined to \$5.5 million a year. This represented over a quarter of all programme expenditure, still too high a proportion in the view of most Unicef policy-makers. The Unicef stance was growing progressively tougher towards the standards of the campaigns it was supporting and others for which its support was requested. Part of the reason was its own organizational evolution and a desire to face the challenges of the UN's first 'Development Decade' by moving into broader programme areas and concentrating less on being a supplier of drugs, vaccines and other material to the narrow objective of disease control. The other part was that many of the programmes for malaria eradication it had originally supported were not doing well. Most were in poorer, and therefore more problematic, countries—or in countries which, despite the most resolute attempts to overcome setbacks, had not managed to end spraying operations in all malarious areas.

In the face of Unicef's palpable determination to reduce its support for malaria eradication, WHO showed concern. WHO Director-General, Dr Marcolino Gomez Candau of Brazil, was very committed to malaria eradication: his enthusiasm had been fuelled by Fred Soper while employed in his country's insect-borne disease service. Candau attended the June 1961 session of the Executive Board to ask Unicef to maintain its financial support. Although the Board re-affirmed the \$10 million ceiling for malaria projects, in practice no effort was made thereafter to reach it.

Unicef's disenchantment was strongly influenced by what was seen as the lack of commitment displayed by certain governments whose vigour in trying to eradicate malaria dwindled when serious problems emerged. It argued that where insufficient interest and support was displayed within the country itself, there was little Unicef could do. In certain countries like India, Ceylon and Taiwan, malaria eradication was proceeding convincingly towards its goal because commitment and resources were assured, and the mechanisms for consolidation were receiving due attention. Elsewhere, there was simply no point in throwing money away, especially as a poor effort at malaria eradication might succeed in reducing a population's acquired immunity to the disease and make them even more vulnerable to

its resurgence. After 1961, Unicef began to withdraw from a number of 'pre-eradication' programmes in Africa which were not preventing the transmission of malaria and therefore could not lead to national eradication campaigns.

In January 1964, the Unicef Board again stiffened the organization's policy on malaria eradication. Apart from ongoing commitments to well-run programmes in which Unicef had been involved from the outset, such as that in Mexico, or campaigns for which there were other long-standing commitments, the conditions attached to new support for malaria programmes were so stringent as to mean that it was almost unobtainable. Unicef had effectively given notice to malaria eradication.

From this point onwards, it preferred to combat malaria and other diseases by supporting the spread of basic health services, particularly those for maternal and child health. If a ministry of health requested supplies of chemoprophylaxis or other antimalaria weapons to be used by health centres alongside other curative and preventive therapies for infectious disease, Unicef was willing to assist. But no more support was forthcoming for autonomous malaria services with their squads of spraymen and convoys of vehicles. What had once been their much-vaunted autonomy now became a black mark against them in countries which had more medical personnel dealing with malaria than with anything else. 'Integration' of malaria personnel into the mainstream of health services now became the favoured policy. Sometimes these shifts in New York and Geneva were hard for Unicef and WHO staff in the field to explain to the governments they had cajoled into carrying out the original strategy.

Whatever Unicef felt about the necessity for reducing its own commitments, as the 1960s wore on the enthusiasts for malaria eradication could still point to significant progress towards their goal. By the middle of the decade, the attack phase finally passed its peak. In 1960, forty per cent of the target population were under attack. By 1964, that proportion had declined to twenty-five per cent, or 372 million people; forty-six per cent, or 686 million, were living in areas which had reached consolidation or from which malaria had been finally eradicated. It was a tremendous advance, even if it was not the kind of advance the prophets of eradication had promised. Except in Africa—and it was a large exception—malaria was firmly in retreat.

The question now appeared to be the cost and complexities of going the last mile. It seemed to many that there was no 'last mile', just endless expensive and possibly-irrelevant miles beyond each last one, and that the equation between investment and results had become hopelessly unbalanced. Even the threat of the DDT-proof super-mosquito—the original justification for the goal—appeared less compelling.

There was also the inevitable school of thought which felt that, having got so far, the goal should not be abandoned at the critical moment. For

some who had believed in the dream of a world free of a vicious disease, there was a deep emotional resistance to the idea that, after all, when science and mathematics said it was possible and when the best wills had been put to discovering the best ways, the dream was not attainable. Opinions were deeply divided—within ministries of health and between them, within the international assistance organizations and between them.

Unicef had by this stage given up agonizing over whether eradication was practicable or not. It was not willing to commit more than a certain proportion of its resources to any one disease and that was that. Although it was never explicitly stated, in the early 1960s Unicef psychologically abandoned malaria eradication. The essence of eradication was that it was an all-or-nothing proposition. As the insect-borne pioneers had demonstrated over and over again, whatever weapon you flung against a mosquito and its occupying parasite it would cause them to retreat; and if you flung it en masse, they would retreat en masse. But when you relaxed, even by a small amount, you allowed vector and plasmodia their chance of come-back—which invariably they took. If you discontinued the onslaught in one country, infected man or infected mosquito would sooner or later cross the border from another.

Fred Soper went to his grave still believing that throughout the world a generation of children was being sacrificed to malaria on the spurious grounds that local health units must first be put in place before the plasmodia could be banished. But the experiences of Soper and others like him were garnered in a different world—one where authority and autonomy, exercised with the panache of a superb field marshal, could inflict health on a population whether they chose to co-operate or not. By the 1960s, those halcyon days had vanished.

In the end, it was not the organizational and administrative failures on the battlefield which drove home the nail in the coffin of malaria eradication. It was certainly true that many governments, which really could not have done otherwise once the real demands of effective consolidation through a health service network were understood, did not commit the necessary financial resources, nor did they organize their operations to the 'minimum' standard of perfection. Ultimately, however, the technical problems turned out to be more than a match for organizational perfection.

The boldest international public-health endeavour of all time was defeated by the creatures of the living world. Mosquito and parasite, particularly *anopheles gambiae* and *plasmodium falciparum*, were able to adapt their biological or behavioural performance too fast for the campaign strategists to catch up. Conniving in their victory was the other malaria vector, man, who did the opposite. He did not adapt his social behaviour to the campaigns, and the strategists' notion that the law—backed up if

necessary by the police—could make him do so proved naive. Such ideas might have worked in a plantation economy or in a highly-organized society, but most malarious areas were neither. The unwitting bond between man and mosquito proved as strong as that between mosquito and parasite in defeating the goal of malaria eradication.

Certain species of *anopheles* mosquito, as forecast, developed resistance to DDT and other chlorinated hydrocarbon insecticides. What had not been anticipated, however, was that some mosquitoes would find the poison irritable and unpleasant and learn to avoid it. Others had marked tendencies towards 'exophily' and 'exophagy', terms which began to appear in the literature and meant that they preferred the outdoor life, particularly alfresco feeding.

In Africa's savannah regions, *anopheles gambiae* was a persistent non-conformist, which was why no 'pre-eradication' scheme ever defeated it. Even where the chances looked hopeful—for example in the islands of Zanzibar and Pemba off the East African coast—all efforts to design a spraying programme to defeat the mosquito failed: it hid in the coral. Man helped it elude its attackers. New dwellings sprouted up without permission; itinerant workers with plasmodia in their bloodstream arrived from the mainland for the clove-picking season. The man-mosquito alliance proved unbeatable—and in 1968 Unicef withdrew its assistance.

Man was not deliberately perverse. Most of the people whose flesh the mosquitoes greedily sought could not be expected to understand fully upon what precise mathematical formulations malaria eradication depended. In tropical countries, many people took the advantage of the cool of the evening to sit and socialize out of doors; and some preferred to sleep outside rather than in the cramped and airless interior of a modest dwelling. Some spent virtually their whole lives out of doors, living in tents and migrating with their livestock and the season. Among nomadic peoples, no amount of understanding of the feeding habits of mosquitoes could have made a difference. In southern Iran, for example, not only did the mosquito become DDT-resistant, but the movements of nomad groups between grazing grounds made it impossible to carry out surveillance and case detection. This was another programme from which Unicef eventually phased out.

In many parts of Africa, even sedentary peoples moved with the farming season. When the time came for planting or harvesting, they went to live in a different hut on a distant patch of land. If migration was part of people's way of life and their food supply depended on it, they were unlikely to change it because of visits from antimalaria sprayers. Among people who did stay in their village all year round, house repairs—plastering or filling in cracks in the walls—did not stop because of DDT. Some materials used for building—mud for example—absorbed insecticide and deprived it of its potency. In many places, once the insect population was decimated,

people refused entry to the spray teams, law or no law. They did not see why strangers should upset their lives and violate their privacy to no useful purpose.

The malaria eradication campaign in Mexico, the largest to receive Unicef assistance, made great progress in its early years. But Mexico was one of the countries whose 'problem areas' defeated all the government's administrative excellence and, by the mid-1960s, seemed to indicate that the technical feasibility of malaria eradication might after all be an illusion. Over 4.5 million people lived in problem areas where the local *anopheles* resolutely held out against DDT and its alternative, dieldrin.

Every variation of attack was tried: the spray cycle was stepped up to four times a year; 84,000 people were routinely given antimalarials; larvicides were brought into use; where people slept outside to escape bugs in their bedding, the spray teams attacked the bugs to tempt people back inside.

The detection of a hard core of persistently smouldering malaria transmission was a setback in Mexico and elsewhere, which WHO described in 1966 as a 'greater challenge than might at first appear'. At the least, it meant more expense. In Mexico, Unicef agreed in 1965 to spend a final \$3.5 million to bring problem areas into consolidation. The effort was inconclusive. In the late-1960s, Unicef withdrew assistance even from Mexico. By this time USAID had also begun to back-pedal on its commitments.

Malaria eradication had lost its glamour. In 1968, it received a mortal blow. Ceylon, whose drop in malaria from 2.7 million cases in 1946 to seventeen in 1963 was among the most phenomenal successes of any programme, ceased spraying altogether in 1967. In 1968–69, malaria came back with a vengeance: over a million people were infected.

While this disaster was still fresh in everyone's mind, DDT was becoming the prime target of conservationist groups in the US and Europe. Its miracle property—the toxic residue which did not go away—had become a symbol of man's determination to poison his planet. As a result of the opprobrium poured upon DDT, its manufacture went into steep decline and many countries banned its use altogether.

US support for malaria eradication also rapidly declined. In 1970, WHO carried out a soul-searching review of the strategy, and laid its conclusions before the World Health Assembly. Current methods for malaria eradication, the report stated, 'demand a degree of efficiency often unobtainable under existing conditions in certain malarious areas of the world'. Until simpler and cheaper methods could be devised, WHO recommended malaria control. Fifteen years on, with many painful lessons learned, the original prescription was reinstated. Nearly 1000 million people had been reached and protected from endemic malaria; but reaching the 360 million still unprotected by any form of specific programme—most

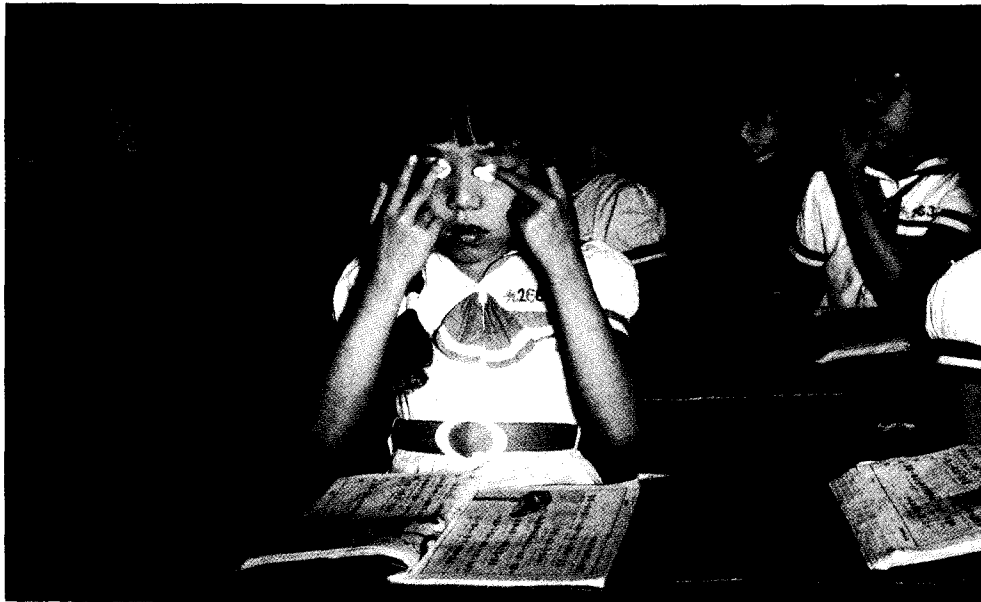
of whom were in Africa—was still beyond the horizon. Psychologically, the corner had been turned.

There are few people today who believe that with money, men and administration, malaria could have been, or could yet be, globally eradicated. For some, there is a painful memory of an endeavour to which they committed their best working years and were forced to abandon in the face of overwhelming evidence that it could not succeed. A particular circumstance—the threat of what might happen as a result of *anopheles* resistance to DDT—had allowed the goal to be set. By the time perceptions changed about the relative importance of the interaction between mosquito and DDT to the epidemiology of malaria and attempts to interfere with it, there seemed to be no going back. But going forward meant that when all the high hopes were finally dashed, disenchantment replaced them. Disillusion with the attempt was out of proportion to its failures.

The decline in resources for malaria programmes was one reason for the resurgence of the disease in the 1970s. Since then, governments and international organizations have not shown the same will to mount a joint strategy against it. The spread of better and cheaper antimalarial drugs via the health services was the chosen approach; to some of the old malaria campaigners it seemed a tame and passive creature beside the heroic efforts of days gone by. Now a new breakthrough—an equivalent to the genuine miracle of DDT in its time—is eagerly awaited and close at hand: a vaccine against the wily and changeable malaria plasmodia. When it comes, strategic and organizational orchestration, backed up by a network of basic health services, will still be needed for any new eradication effort. Perhaps next time it will succeed.

In the meantime, the malaria wheel has gone full circle: from a quinine cure to control; from control to eradication; from eradication back to control; and now back to cure. The early identification of a case of malaria and its prompt treatment is regarded as the first essential of antimalaria services. Spraying with residual insecticide as a means of keeping the vector at bay is a long way down the list, the old-fashioned mosquito net or incense coil being less likely to invite biological adaptation. The use of antimalarial drugs as a means of prevention in endemic areas is no longer recommended except for pregnant women: in children, it prevents development of natural immunity and encourages resistance in the parasite. Quick treatment at the first onset of fever, even without a professional diagnosis, is the surest means of saving life and health and of keeping natural selection working against the disease.

The drugs are cheap; the problem is to put them within reach of poor and remote rural families. This still depends on 'surveillance', although that is not the term which would nowadays be used to denote that there is a volunteer in the community trained to look out for tell-tale signs and to do something about them.



In Taiwan alone, more than half the school children used to suffer from painful trachoma. A little girl rubs her eyeballs and lids with soothing antibiotic ointment provided by Unicef in a major antitrachoma drive in the late 1950s. (Unicef/Ling)



In the early 1950s, some sixty-five million Indonesians lived in yaws-infected areas. The target: one million penicillin injections a year to cure the disease. (Unicef/Ling)



Indonesia mounted the world's largest campaign against yaws in the 1950s, employing great numbers of mobile male nurses working in the field.
(Unicef/Ling)

India, 1950: Bombay received much of its milk from buffaloes kept in congested, unsanitary cattle sheds within the city.
(Unicef/Ling)

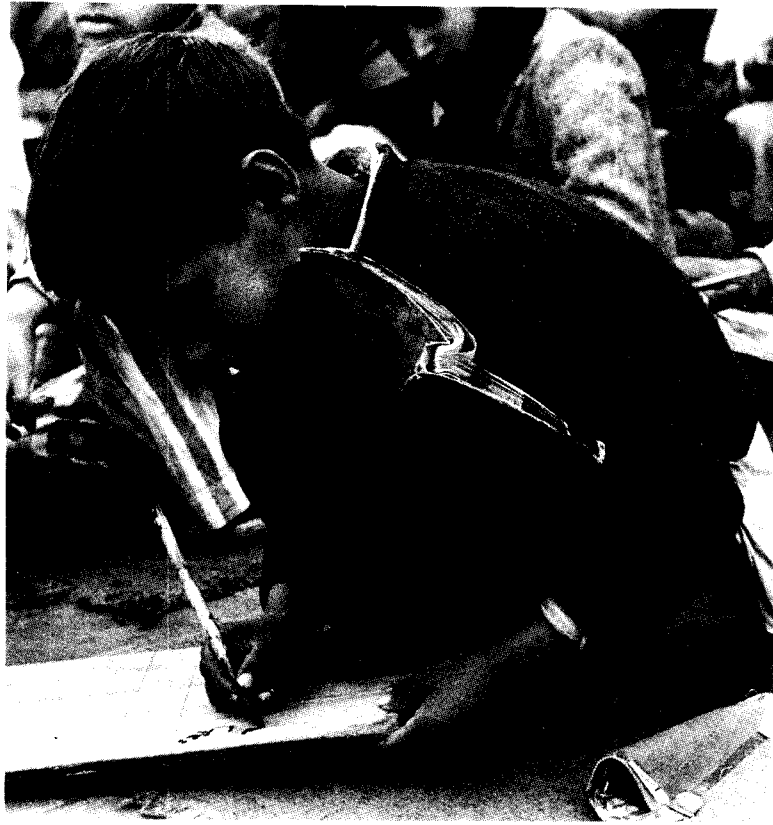


A baby is born in the highlands of Puno, Peru, under the trained hands of a traditional midwife equipped with a Unicef kit who walked three days to reach her 'client'.
(Unicef/Rosler)



A literacy class in Endeber, Ethiopia: part of a national campaign that increased the literacy rate from thirteen per cent in 1974 to thirty-five per cent in 1981.
(Unicef/Campbell)





In primary schools in Pakistan, Unicef supplies of slates, chalks and other educational equipment help get learning underway. (Unicef/Vajrathon)

Equipment and supplies are needed for day-care centres. By 1981, more than 550 such centres had been established in the poorer areas of Puno, Peru, with Unicef assistance. (Unicef/Frank)



Malaria was not eradicated; but, except for the countries of Africa where little progress was made, the effort to bring malaria under control was not a colossal failure. Much was achieved, much was learned, much was built upon both strengths and weaknesses.

In India, eight years of the campaign reduced 100 million malaria cases a year to 80,000. Huge numbers of auxiliary medical personnel engaged in the campaign were then retrained to become multi-purpose health workers. In every malarious country to reach consolidation, infant mortality rates dropped from the hundreds to double digit figures. In a few, the effect of the campaign was to purchase for a few dollars a head a life expectancy equivalent to that of a modern industrialized society. In Mexico and elsewhere, large tracts of previously-unused land were opened up for settlement and brought under cultivation. In many countries, the anti-malaria drive was responsible for underlining the importance of a basic health-service network to consolidate the gains of any disease-control campaign, and setting its growth on track.

In one sense, malaria control was an extraordinary success. It saved so many lives, especially children's, that it created a population explosion. By the late 1960s, this problem—one that some saw as a monster unleashed by thoughtless progenitors of disease-control campaigns—was occupying far more of the world's attention than malaria ever had.

The eradication of malaria awaits a vaccine. The disease for which the technique of vaccination was first developed was smallpox. With great difficulty, Edward Jenner, a late eighteenth-century English physician, persuaded medical and scientific contemporaries to accept the evidence he had put together in support of an observation made to him by country folk: that those exposed to cowpox did not contract smallpox. He also believed that the use of the technique could banish the dreaded and disfiguring disease for good. Jenner was right; but it took nearly 200 years and a concerted global onslaught led by WHO to bring his prophecy to fruition.

A worldwide programme to eradicate smallpox began in 1958. The campaign was revitalized in 1967 following the realization that without a co-ordinated and carefully-designed international effort, even the eradication of a disease technically ideally suited to definitive prevention would not happen.

Launched twelve years after the antimalaria drive began, the smallpox eradication campaign gained from many of its lessons—in particular the need for effective surveillance, and the complications of case-finding in places where health services barely existed. It required a considerable act of faith to go for the world's first organized disease eradication at a time when mass-disease campaigns, with their tendency for a decisive burst to

turn into an endless drain on hard-pressed health budgets, had earned themselves a bad name. Smallpox eradication recouped some of disease control's lost reputation, and provided the world with a spectacular and popular world health success story.

Most of the credit for smallpox eradication rightly went to WHO. The brunt of the expense and the national mobilization of personnel behind the campaigns was borne by the afflicted countries; but the technical weapons and the strategy which put them to work came from WHO's smallpox eradication team. The hideous reputation of the disease and its extreme contagiousness also helped bring in support from countries spending considerable sums on vaccination and travellers' health checks so as to protect their own populations.

Among the international donors, the US, USSR and Sweden were substantial givers of vaccine, fuel and transport. Unicef helped some countries set up their own production units for freeze-dried vaccine and provided vehicles for mobile teams, but it never identified itself closely with the smallpox effort. This was mainly because enthusiasm for the control of specific diseases had given way to helping develop multipurpose mother-and-child health services. Unicef was also influenced by the searing experience of malaria eradication, and the considerable scepticism in its wake over whether any disease was globally eradicable.

Smallpox was, however, a very different proposition from almost every other disease for which a means of prevention lay ready to hand. Compared with malaria (such a frequent cause of death because such a frequent cause of sickness), the smallpox caseload was relatively small; but the effect of contracting the disease was much more likely to be fatal, or at the least, permanently disfiguring. Like leprosy, therefore, it was a disease which struck terror, especially as no cure was available. Unlike leprosy, the incubation period was short—two weeks—and the course of the disease swift and decisive. Outbreaks occurred most often and with greatest destruction in crowded, urban slums into which an outsider had introduced the virus. In the worst of its two forms, *variola major*, the death rate was forty per cent. Since so many victims died, epidemics of this kind of smallpox were usually small-scale and swiftly burned themselves out.

There was another reason why smallpox was exceptionally containable. The virus was neither harboured nor contracted by any animal or insect, and could only be passed from person to person within a relatively short infectious period. During the two weeks or so that the actual pox erupted on the skin, a victim's clothing or bedding or infected skin was highly contagious; but those who survived, ugly though they might have become, could at least reassure themselves that they were permanently immune and non-infectious. This was the characteristic of smallpox which, ultimately, made it susceptible to all-out attack.

The existence of preventive vaccination was the most obvious critical

ingredient, for if a high enough proportion of the population could be successfully immunized, the disease would spontaneously die out. Unfortunately it was discovered in the early 1960s that, because smallpox was so contagious, in highly endemic areas this proportion had to be virtually 100 per cent. In many afflicted countries, 100 per cent coverage for any disease control campaign was known to be out of the question. But because of the stability of the virus and its fixed pattern of transmission, the smallpox eradicators could use a back-up strategy. Instead of blanket vaccination, they concentrated on finding cases, isolating them, vaccinating every contact, and quarantining them until the danger of incubation was over. Smallpox was thereby trapped and could go no further. Once the patients in a family or community died or recovered, the source of infection was eliminated.

When the real push for global eradication began, the number of reported smallpox cases in the world was fluctuating between 50,000 and 100,000 a year, and this was thought to represent only a fraction of the total. In 1967, the first year of the newly-intensified campaign, it rose to 132,000: a sign that the campaign, as tended to happen, was flushing its target's dimensions into the open. Apart from a reservoir in Brazil, which also threatened countries on its borders, smallpox was nearly eradicated from the Americas. The main reservoirs were in certain countries of Asia—Afghanistan, Burma, India, Indonesia, Pakistan and Nepal—where *variola major* was common; and in most of the countries of Africa south of the Sahara, where the usual form was *variola minor*, a virus somewhat less terrifying since the death rate was only one in a hundred.

Most countries with endemic smallpox had already embarked on vaccination programmes; now WHO proposed that these be stepped up for three- or four-year periods. The weapons for vaccination were specially streamlined. Vaccinators used either bifurcated needles for scratching the skin, which conserved vaccine more carefully, or jet injectors in areas where there was a shortage of fully-trained personnel. Stringent tests guaranteed the potency of vaccine whether imported or locally-produced. WHO recommended that mass vaccination be carried out by mobile teams in all endemic areas; once this was completed, the existing health services should maintain the coverage by vaccinating travellers and the newborn.

The strategy for malaria eradication had viewed surveillance as a campaign element which overlapped and followed the attack phase. With smallpox eradication, although mopping up intractable 'foci' was originally the identical intention, surveillance quickly overtook attack and became the cornerstone of campaign strategy. During the campaign in Nigeria, a shortage of vaccine inspired planners to concentrate on tracking down cases and confining them, if necessary by a policeman at the door. The available vaccine could then be sparingly applied to contacts only. Even in areas where vaccination coverage rates were low, this method stopped

transmission in its tracks. 'Surveillance-containment'—a gentler term for the modern version of quarantine—was then introduced in countries with similarly spread-out populations; it was successful in both Brazil and Indonesia, whose last smallpox cases were detected in 1971 and 1972 respectively.

The strategy was further refined in 1973 for the densely-populated countries of Asia. First in India, and later elsewhere, thousands of teams of case-finders, working with the co-operation of health institutions and schools, and with the knowledge of where the last outbreak had occurred, tracked down every possible and actual smallpox victim.

The disease gave itself away by its ugly pox both during and after infection. The discovery of a possible case—it might turn out to be something less serious, such as chickenpox—would prompt 'flying squad' action to make a diagnosis, identify all contacts, and swiftly contain the spread of infection. In India, over 150,000 searchers took part in active surveillance, and the public was offered a financial reward for sightings of pox.

By 1975, the number of smallpox cases in the world had dropped to 2130 and, in less than ten years, the number of countries where the disease could still be found had dropped from thirty to three: India, Bangladesh, and Ethiopia. By the end of the year, the last case of *variola major* was reported in Bangladesh.

The resources for a concentrated attack on *variola minor's* last redoubt were shifted to Ethiopia, where the lack of roads and any kind of health or social service infrastructure in most of the countryside presented organizers with great logistical difficulties. Smallpox left Ethiopia in August 1976; unfortunately not before nomads in the south-east had carried the virus across the border into Somalia, where an epidemic occurred in mid-1977. In October, the last case of *variola minor* was reported in the town of Merca; in 1979, the victim was declared to have been the last smallpox case in the world!

In May 1980, the World Health Assembly declared the disease extinct. Vaccine supplies have since been kept in laboratories around the world against the possibility of an outbreak. The only known cases since 1977 were the result of a laboratory accident. WHO's offer of \$1000 reward for the report of a confirmed case in any part of the world still awaits collection.

In the case of smallpox, due to the behaviour of the disease, the technical means to hand and the relatively low caseload, the equation of investment against results made eradication possible.

The costs of going the 'last mile' even with smallpox were not inconsiderable; during the final outbreak of the disease in Somalia in June 1977, twenty-four WHO epidemiologists and 3500 national staff—a huge proportion of the health personnel in such a poor country even including semi-

trained auxiliaries—were employed full-time on the exclusive task of looking for cases. Between 1977 and 1979, there continued to be 1500 Somali personnel and twenty WHO staff on nothing but smallpox hunting duties. At the same time, there were 1200 searchers in neighbouring Ethiopia, and 265 in neighbouring Kenya. Surveillance was also initiated in Djibouti, North and South Yemen, and during the annual pilgrimage to Mecca.

This kind of mass effort to make absolutely sure of the enemy's conquest could only be justified by the technical certainty of the methods used to obtain the result. The investment of around \$300 million, one-third of which came from international sources and two-thirds of which was borne by the afflicted countries, saved the world around \$1000 million annually in vaccine, vaccine administration, applying international health regulations and other costs. Most of that saving has, however, been to the budgets of industrialized countries which can afford upfront investments against a hoped-for, but nonetheless risky, target.

Devoting proportionately much larger amounts of the health budgets of developing countries to mass campaigns for disease control is not a strategy necessarily vindicated by the success of smallpox eradication. So far, WHO has not advocated any further mass eradication onslaughts; polio is the only disease talked of as a possible candidate.

The mass-disease campaigns which did so much during the 1950s and 1960s to relieve the fears and the sufferings of the family of man taught the practitioners of international public health a number of lessons. Not the least important was that disease control cannot be consolidated without a network of health services and health personnel reaching out into every nook and cranny of the land. Another was that people have to want to join in. People have to want to be cured of a particular disease, which is usually easy; they also have to want to understand how to prevent it, which is extremely difficult among the poor, usually ill-informed and sometimes superstitious inhabitants of dusty and distant villages.

When the pendulum swung away from the disease-control campaign, it was this conundrum that the public-health experts began to address, and it is the conundrum they are still trying to unlock today.

Main sources

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