Railroads, disease, and tropical medicine in Brazil under the First Republic

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Abstract

The article explores the impact of malaria on infrastructure works – above all, railroads – under the republican drive towards modernization. Railways helped tie the territory together and foster the symbolic and material expansion of the Brazilian nation. The scientists entrusted with vanquishing such epidemic outbreaks did not just conduct campaigns; they also undertook painstaking observations of aspects of the disease, including its relations to hosts and the environment, thus contributing to the production of new knowledge of malaria and to the institutionalization of a new field in Brazil, then taking root in Europe's colonies: "tropical medicine." The article shows the ties between these innovations (especially the theory of domiciliary infection) and the sanitary campaigns that helped the railways, which in the 1920s were followed by a new phase in Brazil's anti-malaria efforts.

Keywords: railroad, malaria, tropical medicine, medical entomology, theory of domiciliary infection, Brazil.

In this article, we analyze the relation between railroads, disease, and tropical medicine from the 1890s to the 1920s, with our focus on malaria. Each term in this equation has its own historical dynamics. We show how the three were intertwined in this period, marked by the growth of the domestic market and by initiatives to explore the country's vast interior and make it part of the state, then dominated by coffee growers and other social groups in Southeast Brazil. The period in which the First Republic was instated and reached its apex was also characterized by the strengthening of scientific institutions founded in the closing decade of the nineteenth century, which played a fundamental role in research and in the practical initiatives meant to overcome roadblocks to the capitalist economic and social expansion flourishing along Brazil's coast. As the railroads penetrated the interior and tied the national territory together, they enjoyed the benefit of relatively successful sanitation endeavors. At the same time, they prompted valuable research that helped to shape tropical medicine—the medicine that addresses the complex life cycle of parasites in diverse hosts and the very dynamic synergy between these biological processes and the economic cycles of human societies.

Malaria as a scientific and practical problem in the 1880s and 1890s

The final two decades of the nineteenth century saw a rising interest in the mechanisms for transmitting diseases of demonstrated or suspected microbial etiology. As possible culprits, the day's research pointed to water, sewer, food, body wastes, and asymptomatic human carriers, on the one hand, and to dogs, cats, birds, insects, and so on, on the other. Mechanical transmission of germs from stagnant water or rotting matter—like the flies that caught the Eberth bacillus—was considered a possibility. Another notion, albeit accorded lesser weight, was that disease was spread by bloodsucking animals, either directly, through bites to humans, or indirectly, through water that was contaminated with infected insects that had died there, which Patrick Manson believed to be the case with *Culex*, transmitter of filaria.

The Brazilian and foreign medical press published much information and speculation about the role of insects in disease transmission. Flies began to inhabit the imagination of urban populations as an omnipresent source of danger in the midst of (or in substitution of) intangible miasmas. Scientists had trouble making room for these new 'actors' in the webs of soil, water, food, housing, railroads, and human beings that were traveled by alleged pathogenic microbes. Connections were rethought and new components added, but insects often remained strangers in these networks (Tomes, 1998; Benchimol, 1999).

There was much lack of definition surrounding malaria and yellow fever. If Brazilians were noteworthy among hunters of the latter microbe, the most credible theory about malaria first came from Italy. In 1878, Theodor Albrecht Edwin Klebs, along with Corrado Tommasi Crudelli, started researching the germ of this disease in the Roman Campagna. There, in the blood of feverish patients, they found the *Bacillus malariae*. Another discovery stayed hidden in its shadow for some time, made in Algeria by the military doctor Charles Louis Alphonse Laveran, who in 1880 published his first observations on *Oscillaria malariae*, later called *Plasmodium*. The microorganism he described was a protozoan, and although a relation had been drawn between these unicellular animals and both dysentery and surra, there was no conclusive evidence that they caused any major human disease.

The complexity of the life cycles of the animals in this sub-kingdom, the non-existence of a precise classification system, and the problem of finding artificial media in which to grow them made this kind of etiology hard to demonstrate. Eugène Richard, Camilo Golgi, and Ettore Marchiafava demonstrated the parasite's life cycle and drew a relationship between it and both the periodicity of paroxysmal crises and pathological changes, most especially anemia and pigmentation of the spleen and liver. It was only after this research that support for *Bacillus malariae* (or for miasmas) shifted to Laveran's hematozoan, in the late 1880s. Nevertheless, the disease could neither be cultured in vitro nor produced experimentally.

The means of transmission of paludism, which did not appear to be contagious, remained undefined. Manson, based on his work on the filaria cycle, raised the hypothesis that a hematophagous mosquito sucked the hematozoan from the blood of the ailing and, upon dying, transferred it to water; via this water—or via the longstanding airborne mechanism—the parasite would return to man. This was the hypothesis underpinning Ronald Ross's 1894-98 research program, conducted while he was serving as an officer with the Indian Medical Service. MacCallum's studies on the hematozoan of the crow prompted Ross to investigate avian malaria and in this way demonstrate transmission of the bird parasite by mosquitoes of the genus *Culex*. The discovery was first published in the *British Medical Journal*, in 1897, and announced by Manson the following year, at the 66th annual meeting of the British Medical Association.

With Ross hailed as the British Pasteur or Koch (Worboys, 1976, pp. 85, 90, 91; see also Cook, 1996), momentum was gained by efforts to establish the medical field Manson then called "tropical" as an autonomous discipline. Convinced that Patrick Manson could help battle the diseases hindering exploration of British domains in Africa, Asia, and the Middle East, Joseph Chamberlain, Secretary of State for the Colonies, appointed him Medical Officer to the Colonial Service and gave him the support he needed to seal negotiations that led to the founding of the London School of Tropical Medicine and the smaller Liverpool School of Tropical Diseases.[2] The *Journal of Tropical Medicine* and Manson's manual *Tropical Diseases* came out around the same time.

Likewise in 1899, the Italians Giovanni Baptista Grassi, Amico Bignami, and Giuseppe Bastinelli demonstrated that human malaria is transmitted by mosquitoes of the genus *Anopheles*. Painted as the prototypical tropical disease, in other countries malaria was the cornerstone of the line of medicine devoted to studying the life cycle of complex parasites, their vectors, and their relation to the environment.

The Institut für Schiffs- und Tropenkrankheiten—Institute of Maritime and Tropical Disease—was founded in 1900 in Hamburg, Germany. It had its own periodical (*Archiv fur Schiffs- und Tropenhygiene*) as well as reference works much like Manson's manual: Botto Scheube's *Die Krankheiten der warmen Länder* (*The Diseases of Warm Countries*), and Carl Mense's *Handbuch der Tropenkrankheiten* (*Manual of Tropical Diseases*).

Many questions about the malaria parasite remained unanswered, from its evolution in vertebrate and invertebrate hosts to the pathological processes it provoked in the former and the systematics and biology of the latter. Scientists also disagreed about whether malaria was caused by a single species of protozoan—the hypothesis defended by Laveran—or by different species. Camillo Golgi suggested three.[3] These questions produced a vast amount of literature, from the time of Ross's discovery (1898) to the first anti-malaria campaign conducted in Brazil (1905).

This lack of definition notwithstanding, pinpointing how malaria was transmitted had immediate practical consequences and fueled heavy optimism about the possibility of controlling the disease. In expeditions to German dominions in Africa and New Guinea, Robert Koch underscored the use of quinine as the most efficacious method of combating outbreaks of paludism; he also made crucial observations on the role of healthy carriers in its epidemiology (Humphreys, 2001; Eckart, 1988). The British, in turn, prioritized the destruction of vectors in their larval phase, using such measures as the application of petroleum in standing water, as well as water sanitation measures, such as the rectification of rivers, drying up of swamplands, and so on. Furthermore, the British took the lead in the effort to learn about and classify species of the bloodsucking Diptera around the world that might be involved in transmitting malaria and other human and animal diseases caused by protozoa. With the support of both public and private bodies with ties to the colonies, Edwin Ray Lankester, director of the British Museum, sponsored this effort, which included study of the tsetse fly, identified by David Bruce in 1895-96 as transmitter of the trypanosomes responsible for sleeping sickness. In the early 1900s, it fell to the entomologist Frederick Vincent Theobald[4] to inventory the specimens sent to the British Museum by the broad network of collectors mobilized at that time.

Malaria and tropical medicine in Brazil

The late nineteenth century saw heated conflicts over the identification and consequently the prevention and treatment of disease in urban and rural Southeast Brazil, areas in turmoil because of foreign immigration, the change in political regime, the process of industrialization, and the socioeconomic impact of the demise of slavery. The controversy over endemic and epidemic diseases in Brazil illustrates the vital role microbiology was coming to play in public health.

From an institutional standpoint, the key references then were the Instituto Bacteriológico de São Paulo, a unit within the state's Sanitation Service that was created in 1892, and the Instituto Bacteriológico Domingos Freire, a federal institution founded about the same time in Rio de Janeiro and with similar responsibilities (Benchimol, 1999, pp. 223-48, 299-344). Pasteur provided São Paulo officials with the name of Le Dantec (Lemos, 1954, pp. 16-19), who less than one year later—on April 5, 1893—passed leadership of the São Paulo institute to the under-director Adolpho Lutz.

In the 1890s, Lutz, his aids, and some bacteriologists from Rio de Janeiro—especially Francisco Fajardo and Oswaldo Cruz—brought themselves up to date with the studies that the British and Italians were conducting in an effort to firmly establish the clinical presentation and etiology of malaria and to discover its means of transmission. The Brazilians adopted a research program that bore relation to other controversial public health issues.

Lutz found himself drawn into the topic of malaria when he attempted to show that the so-called São Paulo fevers, which many believed to be malarial, were actually typhoid. Lutz had to demonstrate the absence of the plasmodium and the presence of the bacillus of typhoid fever in the São Paulo capital, where epidemics of these '*febres paulistas*' raged. Another side of this endeavor was the effort to identify places where malaria actually occurred within the territory under his jurisdiction. This question was linked to other enigmas of medical and zoological interest: how was *Plasmodium malariae* transmitted; what other species of this genus and what other genera of this phylum of the animal kingdom might be connected with diseases of invertebrates and vertebrates, including humans?[5]

Precisely while Lutz was searching for Laveran's plasmodium, Francisco Fajardo was demonstrating its presence in the blood of malaria sufferers in Rio de Janeiro. Elected an active member of Brazil's National Academy of Medicine in 1893, based on his memoir "O micróbio da malaria" (The malaria microbe), Fajardo also published studies on other topics of the day within the field of experimental medicine in Brazilian and foreign medical periodicals. Lutz received "magnificent preparations" of Laveran hematozoan from him and continued the search for the malaria parasite in humans and animals. Lutz claimed primacy in establishing its presence in the blood of birds: "This is the first time this fact has been verified in Brazil," he wrote in the 1893 Bacteriological Institute report. His investigations into human malaria were focused first on Barra de Santos and the marshy lowlands near that port, followed by the banks of inland rivers; they resulted in a first map of malaria in the state of São Paulo and vicinity. The foci were concentrated in three regions: mainly the coast (Barra de Santos, Guarujá, Rio de Janeiro, and Paranaguá); in the second place, the coastal mountains, particularly around Santos; and lastly, the banks of major inland rivers (the Moji-Guaçu, Tietê, Paraná, and Piracicaba). Between the coastal ranges and these riverbanks lay a zone that was nearly unaffected, right where the capital stood.

In 1897, Adolpho Lutz suddenly found himself face to face with the issue of mosquito transmission of malaria, thanks to the enigma we will describe in the following section.

Railroads and forest malaria (or bromeliad malaria)

The building of railroads in São Paulo came in response to expansion of the coffee crop. The transportation of beans by pack mule, in journeys that lasted for days, was an intolerable hindrance to the development of cropland and of exports.

The first studies on the feasibility of laying track from the inland province capital and main coffee-growing centers to the port of Santos date to the late 1830s. The line was to cross the Serra do Mar mountain range along the stretch known as Serra de Santos or Serra de Cubatão. In 1859, a group led by Irineu Evangelista de Souza—the Baron of Mauá—was awarded a concession by the imperial government to build and operate the line that would connect the port of Santos to Jundiaí. In 1860, the São Paulo Railway Company Limited came into being in London, and two experienced British engineers were hired: James Brunlees and Daniel Makinson Fox. As the first long-distance railway in Brazil, the company's 140-kilometer-long line was opened to traffic on February 16, 1867.

Owing to the large volume of coffee transported to Santos and the growth of rural towns, it was soon necessary to double the line. In 1895, a new track began to be laid alongside the first, and it was inaugurated on December 28, 1901.[6] In 1897-98, a malaria epidemic assailed the railroad workers, along the stretch of heavy woodland climbing the mountains. The environment differed greatly from that of the swampy plains usually associated with the disease. Cases occurred both at the tops of the range and on its slopes, "in very steep places completely devoid of swamps, and were not observed where the line went through the swamps," Adolpho Lutz wrote in his 1897 report.

Outbreaks of malaria had been hitting other railway workyards, like Mauá, near Rio de Janeiro, and Guarujá, near Santos. In his 1898 report, Lutz only noted that the large number of cases in Serra de Santos could be blamed on "the agglomeration of workers in a zone that was usually almost deserted." In later reports, he never mentioned the subject again. Malaria remained on the agenda even after its means of transmission was deciphered in 1898-99, but it was almost always linked with its predictable habitats: the swampy plains and valleys of the state of São Paulo. It was only in 1903 that Lutz revealed how complex the enigma of the Santos mountain outbreak had been—a subject to which he had devoted all those many years trying to figure out.

The main part of the railway between São Paulo and Santos connected the plains, lying slightly above sea level, to the crest of the chain, whose lowest peak was about 900 meters. The line passed through thick forest, tunnels, and viaducts and over canyons and ravines cut by myriad streams. The steep gradient meant there were many waterfalls, and no possibility of standing water. Eyewitnesses told Lutz that during work on the first line, intermittent fevers had raged among the workers, but the problem had stopped once work was completed; new cases had not been observed among passengers, service personnel, or the few families that lived along the track.

While the new line was being opened, hundreds of laborers were lodged in huts in the woods, connected by trails. Numerous cases of intermittent fever then reappeared, "often times affecting most of the dwellers in a hut in a few days" (Lutz, 1903, in Benchimol and Sá, 2005, p. 760). Blood tests showed Lutz that the workers were indeed suffering from malaria. The epidemic's intriguing characteristics prompted him to spend some nights in a house there, where the resident had fallen ill:

> On the first night, following a very hot day, while we were sitting next to a lamp, countless biting insects soon appeared. They included *Simulium pertinax* Kollar, some *Culicidae*, rather commonplace and familiar to me, and a species that I had not yet seen. […] Despite its dainty size, it proved a voracious bloodsucker. […] This mosquito's bites are less painful than those of some other species. Owing to these circumstances, they are not felt by certain people, so that the species, which flies mainly around dusk, goes easily unnoticed. I was immediately certain that I had found the mosquito I was looking for, even though the characteristics of malaria transmitters were still unknown at that time. When shortly thereafter it was discovered that these should be looked for among species of the genus *Anopheles*, I was satisfied to see that the new species was in fact an *Anopheles* (ibid., p. 761).

With the suspect species in hand, Lutz set about identifying the local deposits of water that would be appropriate for its breeding. Thanks to earlier studies on plants that accumulate water among their leaves, he soon located the habitat of the malaria transmitter in the Serra do Mar.

"Waldmosquitoes und Waldmalaria" (Forest mosquitoes and forest malaria) was published in *Centralblatt für Bakteriologie, Parasitenkunde und Infektionskrankheiten* (v. 33, no. 4, 1903, pp. 282-92).[7] In the interval between his first observations—based, according to Gadelha (1994, p. 178), on his "immediate, almost intuitive conviction"—and publication of its discovery, Lutz was able to ascertain that most forest mosquitoes spend their larval phase in the water of bromeliads.

The institution of tropical medicine and medical entomology in Brazil

Adolpho Lutz was one of the most productive members of the network put in place by the British to catalog mosquitoes around the world. The first contact with him was made on March 24, 1899, through the British Consulate General, and Lutz sent the first shipment of over forty species to the British Museum in June 1899. This initiated an intense exchange, not only of specimens but also of information on the group, which was the subject of major taxonomic confusion. Coordinated by Theobald, the endeavor resulted in a monumental five-volume monograph published between 1901 and 1910. Because the *Diptera* were collected for their potential medical significance, it was vital to learn about their life cycles and habits, especially their proximity to human populations and their attraction to human blood.

Among the many new species captured and described by Lutz, the most important was the one still recognized today as the primary vector of so-called bromeliad malaria, which occurs epidemically along the coast of São Paulo state and is endemic from São Paulo to Rio Grande do Sul. Called *Anopheles lutzii* (now *A. cruzii*), it is the only known natural vector of simian malaria in the Americas (Consoli and Oliveira, 1994).

The golden age of medical entomology was then coming to life, marked by an intense exchange between different fields. During the whole of the nineteenth century, only 42 species had been described in the family of *Culicidae*, while over 200 new species were described in the first decade of the twentieth alone (Lane, 1953), most by Theobald, Lutz, and Daniel William Coquillett, of the US.

Lutz was the advisor of Celestino Bourroul, who wrote Brazil's first medical thesis in medical entomology.[8] By the time "Waldmosquitoes und Waldmalaria" was published (1903), Lutz had become the center of the network of physicians in Brazil focused on this burgeoning field of research.

Oswaldo Cruz made the acquaintance of the director of the Instituto Bacteriológico de São Paulo around the same time as Fajardo. The three were major protagonists in the cholera epidemic that tore through the Paraíba valley in 1894-95. The following year, Cruz traveled to France to undertake further studies at the Pasteur Institute (Guerra, 1940, pp. 31-42). He followed the heated debates in Brazil about the etiology and transmission of yellow fever from there. He returned to Brazil in 1899, the year the country was hit by the bubonic plague pandemic. Together with Adolpho Lutz, he helped establish diagnosis of the plague at the port of Santos (Cruz, 1900).

Because of problems obtaining both Haffkine's vaccine and the anti-plague serum developed by Yersin, the São Paulo government pushed through the urgent creation of a laboratory to manufacture them locally. At the Fazenda Butantan, under the direction of Vital Brazil, an appendix of the Instituto Bacteriológico commenced operations in late 1900, shortly after Rio de Janeiro's counterpart, the Instituto Soroterápico Federal, was set up at Manguinhos (Benchimol and Teixeira, 1993). The Baron of Pedro Afonso was made head director, with Oswaldo Cruz appointed technical director, a post he held until December 1902, when he was promoted to the top position. He had already published *Contribuição para o estudo dos culicídeos do Rio de Janeiro* (1901),[9] about malaria foci on the outskirts of the capital, that is, in Jardim Botânico, an outlying area that had shortly before been connected to the urban zone by tramway, and in Sarapuí, in the Baixada Fluminense, alongside the Central do Brasil railway.

At the turn of the twentieth century, another disease became a focus of Mansonian tropical medicine, thereby strengthening medical entomology as a specialty. In 1900, a medical-military commission in Cuba, headed by Walter Reed, confirmed the hypothesis formulated twenty years earlier by Cuban physician Carlos Juan Finlay: the transmission of yellow fever by *Culicidae*. The 'Havana theory'—as it was known in Brazil—was soon guiding the campaigns of William Gorgas in Cuba's capital and of Emílio Ribas and Adolpho Lutz in São Paulo. In 1902-03, the latter in fact replicated Reed's experiments in order to neutralize the reactions of physicians who still held to the belief that the disease agents were the bacteria or fungi that had been blamed as agents of the disease for the previous twenty years.

In 1901, in an attachment to an article by Ribas entitled "O mosquito como agente da propagação da febre amarela" (The mosquito as an agent in the dissemination of yellow fever), Lutz described two species habitually found in households, *Culex taeniatus* and *Culex fasciatus*; in late 1901, Theobald incorporated these into the genus *Stegomyia*, as *Stegomyia fasciata*. Transmission of yellow fever 'solely' by this mosquito formed the crux of the clash between the 'exclusivists', led by Oswaldo Cruz, and the 'unconvinced', which transpired at the 5th Brazilian Congress of Medicine and Surgery, held in Rio de Janeiro in 1903.[10] Still under judgment, the theses of the Reed Commission were verified in the Brazilian capital by medical commissions from France and Germany—in an 'open-air laboratory' that could test the new strategy for combating the disease which constituted the Gordian knot of Brazilian public health (Löwy, 1991, pp. 195-279; Benchimol and Sá, 2005).

In Rodrigues Alves' Manifesto to the Nation, made public on November 15, 1902, when he was elected president of the Republic, the new leader defined the main goal of his government as the sanitation of the capital of Brazil (Benchimol, 1992). Rio de Janeiro had lost its ranking as top exporter of coffee to Santos, but had earned its place as a major importer of both merchandise and immigrants, the latter drawn by Brazil's vast hinterland, whose borders were pushed outward by the expansion of the railway, now under government control. Rio was one of the world's fifteen largest ports and third largest of the Americas, trailing behind New York and Buenos Aires.

Teeming seaside neighborhoods were razed and a number of coves disappeared to make room for the new piers, where ships would dock and be unloaded by electric cranes.

Electric power was distributed to the new avenues and buildings of Rio de Janeiro. The backbone of these urban improvements—designed to transform the colonial city into a metropolis resembling Paris—was Central Avenue, which cut through the labyrinthine Old City and destroyed what had been the daily panorama for thousands of people. At the same time, laws and decrees banished "old customs" incompatible with the reigning ideal of civilization.

By about 1910, the avenue's monumental buildings had been erected, almost all in exuberantly eclectic styles. Likewise completed was the imposing architectural complex that Oswaldo Cruz, then director-general of Public Health, built in the suburb of Manguinhos to house the serum therapy institute's new laboratories. This facility was soon baptized with his name: the Instituto Oswaldo Cruz. Cruz was aware of the role that façades played in the public imagination of his day, and these were used to legitimize the research institute in the eyes of public opinion (Stepan, 1976; Benchimol, 1990). Work at the institute was structured into three areas: the manufacture of biological products, research, and teaching—likewise the three pillars of the Pasteur Institute in Paris and which continue defining the Fundação Oswaldo Cruz today. Investigations into human, animal, and, to a lesser extent, plant disease brought the institute in contact with different 'clients' and research communities, reinforcing its social bases of support. The expansion of frontiers also had a geopolitical connotation, echoing the case of European institutes in Africa and Asia. Manguinhos scientists were to venture into the *sertões* of Brazil to study and combat disease, especially malaria. When they placed their expertise at the service of railroads and other projects, they would find themselves up against problems unlike those encountered in urban hubs. They would have the opportunity to study unknown or little-known pathologies and to gather biological material that would profoundly enhance the field of tropical medicine in Brazil.

The problems this medicine sought to elucidate required disciplines and tools that differed somewhat from those of the program that had given wings to the institute: bacteria and related medical technologies. The relevant topics back then included the mechanisms of disease transmission by arthropods and the life cycles of parasites in the environment and in the organic media of successive vertebrate or invertebrate hosts. The study of these questions required knowledge of the classification rules mainly for protozoa but also of their hosts, an understanding of the geographic distribution of the proven or hypothetical disease transmitters and their relation with the environment, and the distribution and clinical and anatomo-pathological characteristics of the human and animal diseases associated with microorganisms and their hematophagous vectors (Worboys, 1996, pp. 181-207; Benchimol and Sá, 2005, pp. 43-457; Caponi, 2003).

During the early days of the Instituto de Manguinhos, entomology was one of the areas that received greatest investments, under the responsibility of Oswaldo Cruz himself, as mentioned earlier, and of Carlos Chagas and Arthur Neiva as well. Chagas sought out the institute in 1902, introduced by Francisco Fajardo, in whose laboratory Chagas had prepared his medical thesis, entitled *Estudos hematológicos no impaludismo* (Hematological studies of paludism).[11] In 1905, Oswaldo Cruz assigned him to combat malaria in Itatinga, São Paulo, where the Companhia Docas de Santos was building a hydroelectric dam and a railroad.

Upon joining Manguinhos in 1906 (pp. 288-9), Arthur Neiva published his first work in entomology.[12] The following two years, he and Chagas combated malaria in Rio de Janeiro's Baixada Fluminense and in other places in the interior of the country. The development of the field of entomology at Manguinhos is closely tied to these campaigns. Until the *Memórias do Instituto Oswaldo Cruz* were launched in 1909, studies were released in *O Brazil-Medico*. The authors' language and their efforts to identify the disease transmitters in Brazil and make a contribution to the systematics of the group reflect their interest in establishing the institute's identity as a research collective within this burgeoning discipline. Until 1910, Lutz would act as the chief intermediary with authorities in the field (Benchimol and Sá, 2006; Benchimol, 2003). Together with Oswaldo Cruz, he served as advisor to **Antônio Gonçalves Peryassú, whose medical thesis**, *Os anophelinos do Brasil* (1908), describes seven genera and nineteen species of anophelines, thirteen considered exclusively Brazilian.

Malaria prevention

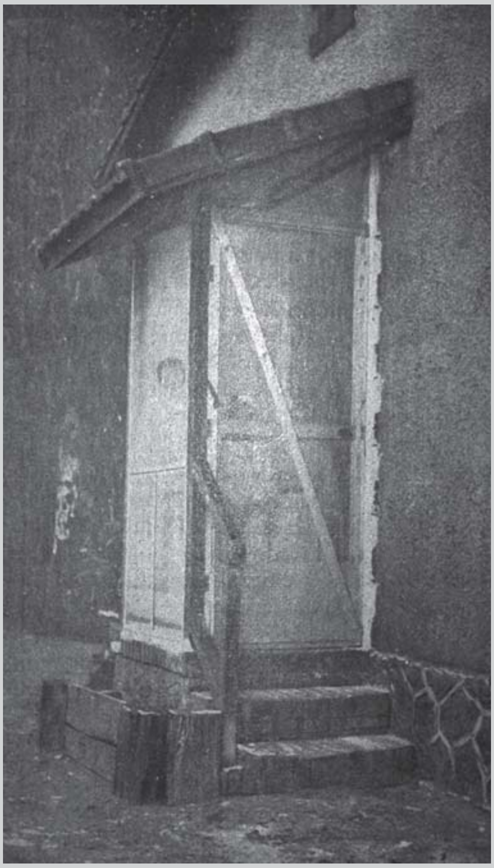
Despite substantial progress in understanding malaria at the turn of the century, the means of fighting it were not obvious. Based on what we might call 'bookish' knowledge about what should be done and based further on the decisive experiences with yellow fever, the young researchers from the Instituto de Manguinhos adapted conventional formulas to the specific circumstances where they intervened. Adjustments and innovations were made necessary, on the one hand, by the ecosystems they encountered and the economic and social interests constraining them and, on the other, by answers to the enigmas then challenging malariologists. "Considerations of an economic order and even the impossibility of carrying out certain processes in practical terms lead us […] to endeavor to adapt prophylactic rules to the local conditions of the experience," advised Chagas.[13]

These rules were synthesized in Laveran's *Prophylaxie du Paludisme* (1903). Edmond Sergent summarized them in a formula when he reported on prevention initiatives in Algeria starting in 1902: "Keep the ailing man from contaminating the *Culicidae* transmitter, keep the parasitic *Culicidae* from infecting the healthy man" (1902, p. 2). This was basically the same formula that guided Oswaldo Cruz in his fight against yellow fever in Rio de Janeiro in 1903-05.

In Itatinga—his very first experience—Chagas followed the recommendation to diversify the work fronts suggested by the classics of his day, while still making very dynamic adaptations; he in fact introduced an innovation that proved most vital in the long run and led him to substantially restrict the focus of subsequent campaigns. Prevention encompassed so-called offensive and defensive methods. The former included "mosquito brigades," an expression coined by Ross to designate the tactic employed in the war against the aquatic larval stage of malaria vectors, involving oils and water sanitation.[14] Lightening up on the militaristic imagery of the approach adopted by Oswaldo Cruz in Rio de Janeiro against yellow fever, Chagas described offensive prevention of malaria as the effort to eradicate the mosquitoes in a zone when possible or to diminish their numbers as much as possible, or, alternatively, to relocate them farther away from people than the greatest radius of their habitual flight.

In the summer of 1902, a mission sent by the Pasteur Institute in Paris, led by Edmond Sergent, kicked off the first anti-malaria campaign in Algeria, in the vicinity of the Alma railroad station, located on the Algers-Constantine stretch of the Compagnie de l'Este-Algerien. Algeria was one of the first sites of anti-malaria initiatives following the identification of *Anopheles* as its transmitter. The goal of the mission was to show that it was possible "to defend a group of Europeans against the inoculators of paludism" (Sergent, 1903, p. 39). These images document individual protection, mechanical protection of housing, and water sanitation measures. Chagas certainly had these examples in mind when he began the Itatinga campaign in 1905-06

Alma Station. Window protected by metal screen. Agents equipped with gloves, wide-brimmed helmets, and tulle veils (Sergent, 1903, p. 50).



Alma Station. Double-screen-door entrance to the gateman's box (Sergent, 1903, p. 48). Right: Clearing brush near the canal before applying petroleum (Sergent, 1903, p. 52).

Applying petroleum to canal. First step. The petroleum is emulsified using a bit of water and then sprayed over the surface (Sergent, 1903, p. 54).

Turning over brush to spread the petroleum (Sergent, 1903, p. 58).

Of Chagas's proposed offensive methods, the effort to wipe out adult mosquitoes within housing units gained priority.

Defensive prevention encompassed individual and collective prevention against mosquito bites through netting, curtains, and so-called mechanical protection of homes. Other methods included 'germicide', 'specific', and 'therapeutic' prevention, meant to eliminate the hematozoan from the bodies of the ill. In the next section, we will see how Chagas used these approaches to defeat the Itatinga epidemic.

The Itatinga hydroelectric power plant

This project traces its origin to businesses that were started up in Rio de Janeiro under the Empire by two French descendents, Candido Gaffrée and Eduardo Palassin Guinle (Sanglard, 2005). They first opened the Aux Tulleries fabric store and then ventured into railroad construction in the Northeast and the states of São Paulo and Rio de Janeiro. In 1888, the company Gaffrée & Guinle won the bid to upgrade the port of Santos and operate its new docks, right when the province was taking over as the leader in coffee exports. Under the Republic, the Companhia Docas de Santos came into being. In 1905, the company purchased a fazenda at the foot of the Serra do Mar mountain range near São João de Itatinga, along the left bank of the Itapanhaú river, with the idea of building a hydroelectric power plant there. Inaugurated on October 10, 1910, the plant had a nominal capacity of 20,000 kVA and was then one of the largest in the country.[15]

Because of the difficulties encountered in transporting men and material in a still uninhabited region dense with mangrove swamps and wetlands, Docas de Santos decided to build a railway using German locomotives from the docks. Work started in 1905 and ended in mid-1906. The 7,250-meter-long stretch ran parallel to the transmission line path. Construction work mobilized (or was to mobilize) some 3,000 people, but nearly ground to a halt between December 1904 and May 1905 because of malaria (cf. Chagas, 1935). Carlos Chagas's work extended from December 1905 to March 1906, therefore coinciding with construction of the railroad.

Chagas first investigated the region's epidemiological conditions to ascertain what types of parasites were hosted by the victims of the disease and learn about the life and work of the population to be protected, especially housing. His research thus covered the region's anopheline species, the hydrographic characteristics of larvae deposits, their relation to distance from dwellings, and hematozoan reservoirs, especially children and older malaria sufferers (Chagas, 1906-07, pp. 12-23).

During the rainy season, this broad marshy, uncultivated lowland turned into a perpetual breeding ground for anophelines, and nights were rough on the people living there. Divided in two groups, they resided in big sheds without any protection against mosquitoes (Chagas, 1905).

Many people had been hit by epidemics in earlier years. Clinical examination and blood tests showed that over 30% were infected, some with acute symptoms and others with parasites in their blood as well as greatly enlarged spleens but no visible signs of illness. Chagas saw three families with almost all of their children infected (1905, pp. 1, 2), "a fact of major importance." He was thinking of Koch's theory about latent paludism in young children. The frequency and duration of the gametes in the children's blood and their resistance to therapeutic intervention made them dangerous reservoirs for the hematozoan. Fortunately, the most common species in Itatinga was *Plasmodium vivax*, while individuals only rarely presented with *Laverania malarice*, which causes the more quinine-resistant 'tropical form' (Chagas, 1908, pp. 6-8). So the sick could be quickly cured.

The campaign began in December 1905. Larvae were eradicated, houses protected, infected children and the chronically ill treated, and those with parasites in their blood isolated (Chagas, 1905). Actually, the first measure that Chagas put into effect was preventive application of quinine to laborers, since the other steps in the program required time. The medication was given with the afternoon meal: 50 cg every three days—a higher dose than the 30 cg recommended in the manuals of Patrick Manson, Botto Scheube, and Carl Mense. Chagas noted neither organic nor social intolerance: "the laborers submitted readily to the use of quinine, showing no appreciable resistance, especially after some time, when convinced of the usefulness and harmlessness of this measure" (1905, p. 2).

In Itatinga, they did work in swamps and streams and dug ditches to rid the two main housing units of breeding sites for anophelines; it seems, however, that larvae-eating fish were not used even though mentioned in the article published in *O Brazil-Medico* (1906-07).

The experience in Itatinga showed Carlos Chagas that there was no efficacious method of individual protection. Although it was customary to chase off mosquitoes with tobacco smoke, the method was deemed useless. Nor did it do any good to grease one's body with scented oils, alleged insecticidal ointments, bitter substances, petroleum lotions, eucalyptus, mint, and so on. The scientific literature called for the use of netting and curtains. But it wasn't enough to cover one's face with a veil or hands with gloves: the mosquito's proboscis had no trouble penetrating clothing. The alternative would be for people to wear thick fabric, something unbearable in a hot climate. According to Chagas, individual protection was only viable for "individuals with a certain degree of education and of a higher social standing"—foremen, engineers, technical specialists, and so on (1906-07, pp. 17/23). Collective prevention measures should be forced on "uncultured" or rebellious laborers, that is, confinement to screened housing. Chagas first used a 1.5 mm mesh. This kept out the most abundant species, *Cellia albipes*, but the tiny *Myzomyia lutzii* could get through, so 1 mm or even 0.5 mm mesh had to be used. The workers' sheds were supposed to have only one entrance, which was accessed by passing through first one and then another screen door; it was important to make sure these doors closed quickly and automatically (1906-07, pp. 17-23).

Both worker resistance to mandatory confinement and economic concerns—that is, not hampering the intensive use of the labor force, day and night—eventually prompted Chagas to change this fundamental rule, but in Itatinga it was still rigorously enforced.

The workers were divided into two groups, infected and unaffected. Those recently infected were confined shortly after the first attack, as were those with enlarged livers or spleens even if no parasites were found in their blood. Chagas was in this case a proponent of the theory developed by the Sergent brothers in Algeria, who believed that an enlarged spleen in and of itself constituted a criterion for positive identification of the infection; in fact, they felt that a region's endemic index could be ascertained based on the percentage of children presenting this clinical alteration.

According to the classic rule, unaffected workers should return to their sheds before dusk and remain there until after dawn. Documents do not tell us whether resistance to this measure weighed in Chagas's decision to ease it, but in his article of 1906-07, he argues that the demand was "too offensive to the well-being" of the laborers, who were used to gathering in the open air after a hard day's work (pp. 20/23).

In proposing a way to soften the rigors of the treatment, the scientist based himself on the vector's habits and on a new understanding of how malaria infection occurred. At the Sixth Congress of Medicine and Surgery, in 1907—when malaria prevention initiatives were already underway in the Baixada Fluminense—Chagas presented entomological observations that backed up his argument. One of them was the delay between the 'solar' and 'culicidean' dusk, which would determine the exact time when malaria sufferers should go inside. He had also ascertained that anophelines only sucked blood outside of dwellings during a brief period, at dusk; "outside this period, one can remain near swamps with impunity, without any fear whatsoever of being bitten. [...] Noted countless times, this observation led us to change the classic precept. [...] For prophylactic purposes, it will suffice to isolate the malaria sufferer for one or two hours at dusk, with this measure done away with the remainder of the night." This would allow for nocturnal work on the railway, which, given the level of economic interest, "well deserved to be taken to the domain of practice" (Chagas, 1908, pp. 3-8).

This last remark shows that Chagas's observations still remained in the experimental realm. They were related to development of the 'theory of domiciliary infection', which we will analyze later on. According to the theory, the infection occurred much more often inside of housing units than outside, therefore making the destruction of winged insects inside of dwellings a priority among protective measures.

The campaign was kicked off in Itatinga on December 18, 1905, and in January of the following year there were sixteen cases. By the end of that month, the main prevention measures were in place: water sanitation, housing protection, isolation, and the administration of quinine to workers. There were only three cases in February—the harshest month for the epidemic in previous years—and all were people living in one unprotected house. By the day Chagas turned in his report in March, no one else had fallen sick, despite heavy rains (Chagas, 1905, p. 3).[16]

Campaigns in the Baixada Fluminense and in the state of Minas Gerais

In February 1907, Neiva and Chagas enacted malaria prevention initiatives in the Baixada Fluminense, about sixty kilometers from the city of Rio de Janeiro. There, headed by José Mattoso Sampaio Correa, the public works department known as the Inspetoria Geral de Obras Públicas was bringing waters from the Xerém and Mantiqueira rivers and their branches to supply the capital. When Chagas left the region three months later, Neiva took over the campaign with the help of Gomes de Faria, also from the Instituto de Manguinhos.[17]

Over 4,000 laborers worked there, and it was ascertained that the majority of inhabitants were infected. The region was infamous for its poor health conditions and it was hard to recruit healthy workers; it had been the site of serious epidemics documented since the early nineteenth century (Ferreira, 1999, pp. 331-51).

A hospital equipped with a laboratory and protected by mosquito-proof metal screens plus a double-screen-door entrance was built in the place known as Ponta dos Trilhos—or End of the Line, since that was where the track along the banks of the Xerém stopped. While a doctor from the public works department supervised hydrographic works meant to neutralize the habitats of malaria transmitters (land filling of swamps, rechanneling of streams and rivers, and so on), Neiva and his assistant put in place stringent chemical and mechanic prophylactic measures: mandatory ingestion of 50 cg of quinine twice a week; continuous treatment of those infected, whether they had been hired for the works or were local residents; isolation of those carrying gametes; protection of water deposits at dwellings and systematic disinfection using pyrethrum; the use of larvae-eating fish; sprinkling petroleum in wells; and destruction of bromeliads (Neiva, 1941, pp. 145-9, 167-98; Chagas Filho, 1993).

Chagas's stay in Xerém was brief because he was appointed to combat malaria in Minas Gerais, in the vicinity of the Bicudo River, a branch of the Das Velhas River between Corinto and Pirapora, where the Railway Central do Brasil was extending its main line. Oswaldo Cruz had been called to action by Miguel Calmon du Pin e Almeida, minister of Viação e Obras Públicas (Transportation Routes and Public Works), because of the "fevers of a serious nature" that were debilitating workers and engineers; he introduced Chagas to the director of the Central do Brasil railroad as the physician who headed up the "paludism prevention services" of the General Directorship of Public Health (Diretoria Geral de Saúde Pública)."[18]

Chagas ascertained that from December 1906 to May 1907, malaria had attacked almost all 1,500 of the laborers that worked on the banks of the Das Velhas River. Given the gravity of this situation, he requested an aid, Belisário Pena, and together they left for the region. They arrived in early June 1907. A study of the place indicated that deposits of larvae could be found both in broad swamps and countless bogs formed by the streams and rivers that crisscrossed the region, as well as in bromeliads in the forests. These permanent, extensive habitats of anopheline species existed all year round, meaning water sanitation and other larvacidal methods would be futile. The mosquitoes invaded dwellings, even in the highest locations and on the coldest days of the year when the parasite had no way of completing its exogenous cycle (which takes place inside the intermediary host), and new infections usually disappeared almost entirely.

The laborers who were attacked during the 1906-07 epidemic resorted to quinine pills with a low percentage of active ingredient, sold at top prices. Believing they had been cured once their symptoms disappeared, they in fact became chronically ill. Chagas was amazed by the number of disabled laborers, who at times presented very serious organic disturbances. Eighty-five percent of the labor force was infected with the serious variety of malaria (Chagas, 1908, pp. 3-6).

Anti-larvae measures were pointless, as were individual or collective measures to protect the healthy, since this contingent of people moved right along with the progression of the railroad. On June 14, 1907, the 'medical commission' defined draconian measures that "engineers, pieceworkers, laborers, and other [company] personnel" were forced to follow. Three measures formed the heart of the document:

> 1st – All of the sick, with no exception for any morbid species, will be sent to infirmaries for treatment, which they will leave when the medical commission so authorizes. 2nd – Individuals deemed dangerous as epidemiological elements will be subject to isolation in protected wagons or sheds, where they will spend the night, going there at dusk, at the time decided by the physicians, and leaving there after the dawn of the day. […] 4th - The periodic use of quinine chlorhydrate, at a dose of 50 centigrams every three days, will be mandatory for all work personnel, including engineers, pieceworkers, etc.[19]

The document's remaining five items stipulated the coercive measures meant to ensure compliance. The pieceworkers were responsible for faithful execution of these measures, under penalty of fines and even dismissal by the engineers; the laborers were liable to immediate dismissal by the pieceworkers, should they disobey; the administrative personnel in charge of keeping track of each worker's hours, who were responsible for distributing quinine, would also be fined or even dismissed if they failed to carry out their orders. Oversight of these services fell to the medical commission, who would receive "from the heads of the Construction and Studies Sections the backing needed for the practical performance of their assignment" (ibid.).

As in Itatinga, Chagas divided the population into unaffected and infected, but only serious cases were isolated, given the enormous proportion of chronic cases (Chagas, 1909, pp. 1-6). Other methods recommended by malariologists were not employed in the Minas campaign, including weekly purges of sheds housing healthy individuals, using sulfur (Chagas, 1908).

Given the huge numbers of infected people and the impossibility of substituting them, the medical commission placed almost all their bets on the curative use of quinine for those infected and the preventive use for those not. The June 1907 'decree' made it obligatory for everyone to use quinine every three days. In his communiqué at the Congress of Medicine in September, Chagas spoke about the quininization of all laborers every two days, with the intent of combating the high number of relapses (1908, pp. 391-99). In his January 1908 report to the Central do Brasil railroad, he mentioned daily administration of quinine for those infected and every three days for those not. According to the calculations he presented, the strategy adopted in Minas resulted in a daily wage increase of 140 réis for each laborer, but this was offset by the benefit of "the useful work of an individual in satisfactory health" (Chagas, 1909, pp. 5, 6).

Chagas and Pena recorded no intolerance to the medicine, despite its extended use over the course of many months. The number of relapses soon fell off—something Chagas attributed to the "radical cure" of almost all those infected during the previous epidemic—and new infections practically disappeared, thanks to systematic administration of quinine and the consequent decline in the number of those who could infect the mosquitoes. "The overall health of the laborers has improved notably […] although we are at the height of summer, in the month of greatest epidemic intensity," wrote Chagas in January 1908 (in Reis, 1909, pp. 4/6). If we are to judge from this text, the coercive methods adopted did not arouse the reactions feared by company directors: "Following well-aimed information on the desirability of this prophylactic method and also owing to the authority of the foremen, we ran into no trouble. [...] It is at present extremely easy to administer, with laborers displaying no reaction whatsoever" (ibid.).

In the 1906-07 article, however, the evaluation had been different: "No small resistance is found to the preventive administration of quinine among laborers. They generally argue that the medicine is dispensable in a state of good health; they raise multiple objections, and blame quinine for almost all organic disturbances that befall them" (Chagas, 1906-07, pp. 23/23). He went on to mention the need for a lengthy information campaign, but we have no way of knowing what was done about it.

In the Baixada Fluminense, mandatory administration of quinine met with fierce resistance. Those responsible for administering quinine summoned the workers. The capsule was given to the worker and if he failed to take it, he was promptly dismissed pursuant to a clause in the contract he had signed. According to Neiva (1941), reactions were common. Someone administering quinine once had to "kill a man who attacked him, because he had been dismissed days before and was incited by the laborers at work." Late payment of personnel brought dissatisfaction to the boiling point. Work was at its peak: over 4,000 toiled away day and night. Neiva was in the hospital, at the end of the line, when he received a call at around one in the afternoon from someone responsible for administering quinine. He had been harassed by a group of over a hundred men, goaded on by an engineer who opposed this prevention measure, and he wanted to know if he should fire all of them. Neiva said yes. That night, the rebels went en masse to the hospital. "You can imagine how hard it was to maintain authority and enforce the orders given," the head of prevention efforts commented later (pp. 189-91).

The documents consulted also record the reaction of the Positivist Apostolate, which since 1903-04 had engaged in a relentless campaign against attempts to make the smallpox vaccine mandatory. The campaign did not let up, not even with the violent epidemic of 1908. What the Apostolate was actually concerned about was a question of principle: "sanitary despotism," that is, the notion that the State had the moral and scientific authority to subject citizens to any norm of a medical nature in order to regulate its health. The pamphlets put out by the positivist church hammered away at the presupposition that the republican regime was based on the separation of temporal and spiritual power, making it imperative to respect individual freedom not only of conscience but also of body.

Days after the *Correio da Manhã* published the "prevention rules" stipulated by the Central do Brasil's medical commission, on June 23, 1907, the Catholic Church and the *Positivist Apostolate* of Brazil published a vehement condemnation of this "moral, political, and scientific monstrosity" in the pages of the *Jornal do Commercio*, on June 28, 1907—or, according to the Apostolate, on Carlemagne 11, 119. In addition to this article by Raimundo Teixeira Mendes, the Apostolate engaged in other interventions in the public life of the country, for example, against the restoration of Catholic symbols in State establishments, Rondon's policy towards "fetishist peoples," and the case of the French ship *Orléanais*, whose passengers, prior to disembarking in Brazil, had been "tyrannically subjected to the plague vaccine" (Mendes, Nov. 1908, pp. 45-7).

In his article on the sanitary despotism that was practiced in Minas Gerais against the proletarians at the service of the State, Teixeira Mendes argued:

> If we recognize that the temporal government, that is, certain men, can force its *opinions* in religion, medicine, philosophy, and so on, on other citizens; if we recognize that the Government has the right to force citizens to take certain *medicine* […] what are the citizens, if not wretched slaves? What is the Government, if not a tormenter victimizing the innocent? (*Jornal do Commercio*, June 28, 1907, p. 5).

It is not unlikely that the engineer who incited the riot in Xerém was sympathetic to the cause, but this is a research topic we will leave aside for now, while we trace the experiences in combating paludism in territories crossed by railroads. We will see how the uprising in the Baixada Fluminense had an impact on the prophylactic strategy against the disease.

Noroeste do Brasil Railway

In July 1905, work began on the railroad that five years later would stretch from Bauru, in São Paulo, to Cuiabá, in Mato Grosso. This project to link the national State to a region that was geographically and culturally distant from the centers of power—first of the Empire and then of the federative Republic—was nothing new. Since the mid-nineteenth century, other projects had their eyes on moving the riches of Central-Western Brazil to the coast. Strategic considerations also played a role in plans to build an overland route between Mato Grosso, Bolivia, and Paraguay, as an alternative to the river ways where the bloody battles of the War of the Triple Alliance had transpired (1864-70). Construction of this railroad was included in the General Transportation Route Plan of 1890 (*Plano Geral de Viação*).[20] That same year the Banco da União do Estado de São Paulo was granted the privilege of building and exploiting a rail line between Uberaba, in Minas Gerais, and Vila de Coxim, in northern Mato Grosso. This route would leave São Paulo out of the picture.

Coffee then accounted for around 70% of Brazilian exports and the territory of Mato Grosso was on the horizon of the São Paulo coffee crop, which was swiftly advancing westward through virgin lands still densely inhabited by natives, especially Caingangues. Rodrigues Alves then revised the 1890 contract. In October 1904, the privilege of building the railroad—now leaving from Bauru towards Cuiabá—was granted to the Companhia de Estradas de Ferro Noroeste do Brasil, which had been formed three months earlier by Brazilian and French-Belgium capital. The track would run through Tietê valley to Itapura, along the banks of the Paraná River on the border with Mato Grosso. The end of the line later became Corumbá, on the right bank of the Paraguay River, on the border with Bolivia. The connection between Mato Grosso and the port of Santos, at the other end, was to be built by the Sorocabana railroad, whose tracks reached Bauru in 1905.

This village of some 600 suddenly became a hub of land grabbers, businessmen, and those willing to sell their labor power to work in the agriculture, commerce, and manufacturing industries that the railway left in its wake. The region was transformed into a Far West. While the contractor responsible for building the Noroeste entrusted so-called *bugreiros*—professional Indian hunters—with the task of annihilating the natives, he subjected his laborers to brutal working conditions: 10-hour days, seven days a week, under suffocating temperatures. "It seems like we are all heart patients," one technical specialist wrote. "Insects annoy men and animals. Tiny bees and nearly unnoticeable mosquitoes come after our eyes, enter our noses, ears, and hair, becoming a true curse" (cited in Castro, 1993, pp. 182, 183). The laborers piled up debts at stores that sold goods at inflated prices, a transaction that only sealed their bondage. Trying to run away demanded the courage to take on the forest, the natives, and the foremen at the service of the contractor. "Whoever enters hell does not get out," Arthur Neiva would often hear the laborers remark (1927, p. 127). Those who did manage to escape would fall ill and find themselves in hospitals in Bauru and São Paulo.

Starting in 1909, the papers—especially worker papers—often carried denunciations of cruelty and mistreatment of laborers, side by side with demands for better food and a shorter workday, one reason being the need to decrease disease rates. The rising mortality rates in the area close to the Tietê River roused the critics. The *Jornal dos Sindicatos dos Ferroviários da Noroeste* raised its voice in protest:

> With part of the malarial zone of the Noroeste railway lying between Córrego Azul and Itapura—which differs in nothing from the regions of Guiana or Central Africa—it seems that the spirit of this evil moves to where Northeast Brazil's paludous zone lies imbedded, for there the inhabitants live in constant dread, either because of the *Stegomias fasciatas* or anophelines that transmit *febres bravas* [tegumentary Leishmaniosis], or because of the basest class of society, that is, those deported by the police, characters who almost always menace the lives of these inhabitants (cited in Castro, 1993, p.189).

In late 1908, the tracks reached Araçatuba, in northwestern São Paulo (Castro, 1993). From there on, the line skirted high crests and ran through the lowlands along the Tietê River, which Lutz had already identified as one of the main malarigenous zones in the state. With the arrival of the railroad and a population lacking immunity, outbreaks of the disease grew more violent. In the 1920s, the directors of the Noroeste would have to reroute this stretch of track, so numerous were the deaths among train workers and passengers.

The terrible working conditions and poor nutrition left the men predisposed to other diseases, including alastrim, worms, dysentery, beriberi, and an unknown pathology, which was baptized "Bauru ulcer." In 1909, almost at the same time, Adolfo Lindenberg, of the Instituto Bacteriológico de São Paulo, and two researchers from the Pasteur Institute in the same city (Antonio Carini and Ulisses Paranhos) identified *Leishmania* in damaged tissue: this was the first case in Brazil of parasitological diagnosis of tegumentary Leishmaniasis, known in European medical literature as Oriental sores or Biskara boils.

The appearance of tegumentary Leishmaniasis among workers on the Noroeste would much later be linked with the abundance of vectors in the region. In fact, one of the stopovers for trains was called Birigui, which in Tupi-Guarani means 'fly that always comes', both then and now a popular name for mosquitoes of the genus *Phlebotomus*.

In May 1908, Sampaio Correa, now as superintendent of the Estradas de Ferra Noroeste do Brasil, hired Arthur Neiva to conduct an anti-malaria campaign in the region. At that point, the railway went only a little beyond Miguel Calmon. "At the expense of all means," Neiva wrote in 1920 (1927, p. 127), the contractors had amassed thousands of workers who were laboring furiously against the dense forest covering the region and who fell one after the other, either victims of malaria or of the *guarantã*[21] of the Caingangues, when they were not corroded by the Bauru ulcer."

Neiva already had some knowledge of the most common species of anopheline in the region, thanks to his January 1908 expedition to Itapura and Mato Grosso in the company of Stanislas von Prowazek, a protozoologist with Hamburg's Institute for Tropical Diseases who spent some months researching and teaching at the Instituto Oswaldo Cruz (Benchimol, 1990).[22]

Neiva's chief weapon against malaria was still the intensive administration of quinine, but the vexations faced in Xerém led him to discard the mandatory system. "When the number of laborers is large, experience had taught me, you cannot demand mandatory administration of quinine" (Neiva, 1941, pp. 189-91). So he resorted to advertising. Sources

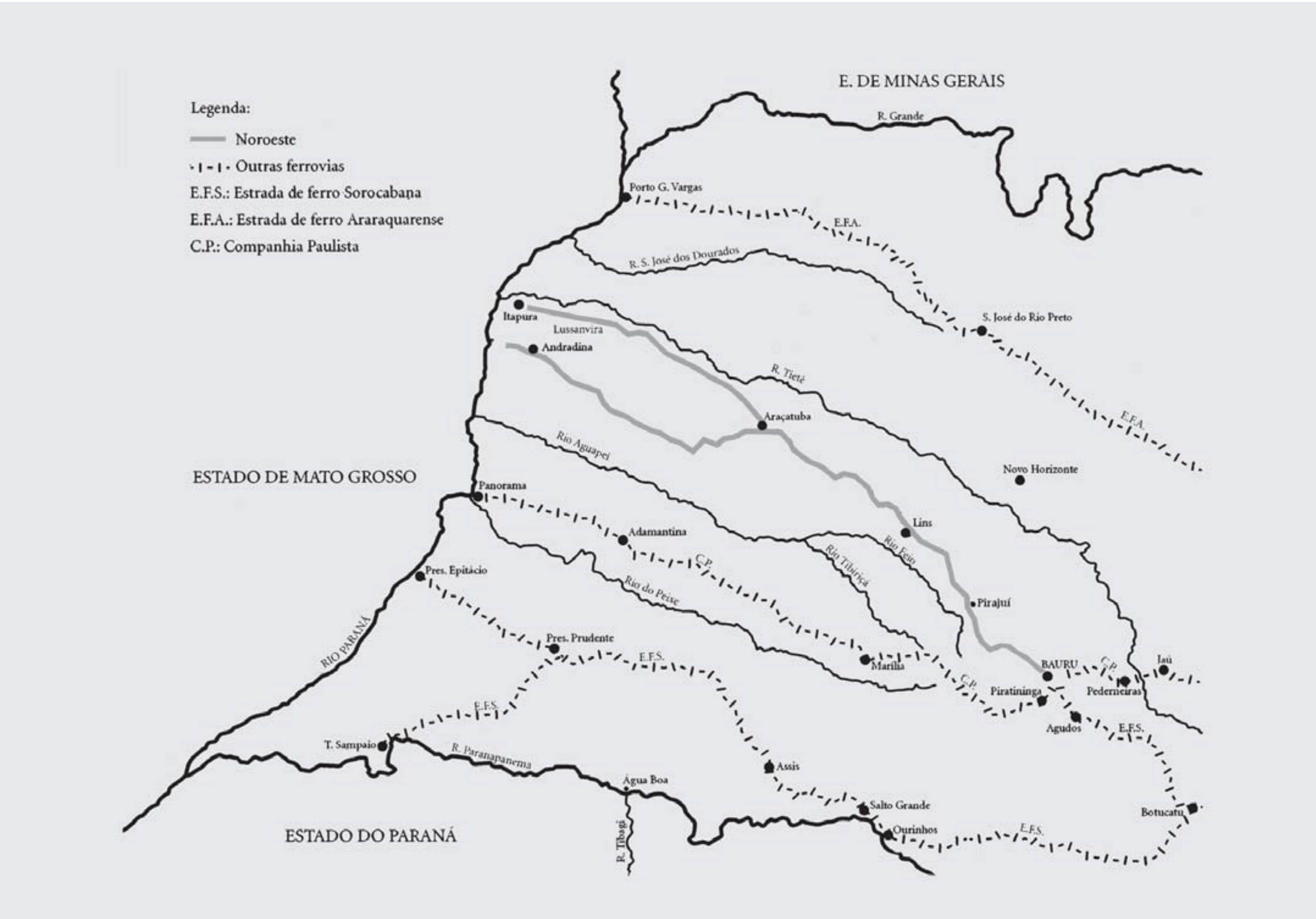


Figure 1 – Noroeste do Brasil railroad track in the state of São Paulo (thick grey line). Starting in Bauru, it reached Itapura in 1910. Given the unhealthy conditions along the Lussanvira branch, a new one was laid: departing Araçatuba, it reached Mato Grosso via Andradina (Queiroz, 2004, p. 35).

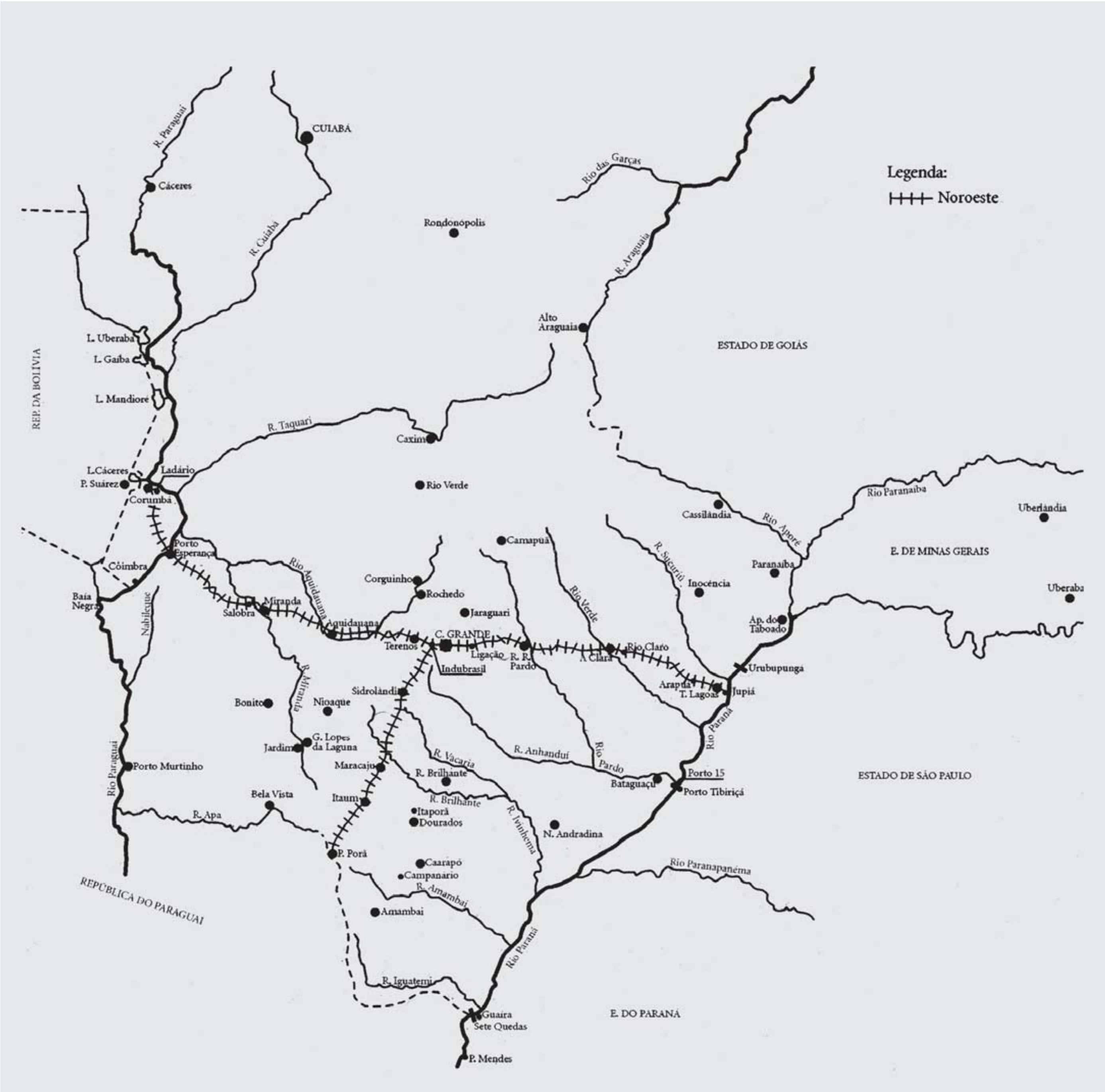


Figure 2 – Noroeste do Brasil railroad track in Mato Grosso (Queiroz, 2004, p. 36). Work on the Itapura-Corumbá stretch began in 1908 in Mato Grosso, starting at Porto Esperança. In 1914, the tracks from Itapura and Porto Esperança met east of Campo Grande, at a point called Ligação. The Bauru-Porto Esperança track was then opened to traffic. It was only in the late 1930s that the track was extended from Porto Esperança towards Corumbá and from Campo Grande towards Ponta Porã, on the border with Paraguay. At the same time, the line between Corumbá and the Bolivian city of Santa Cruz de la Sierra was laid. The 1950 completion of these works brought the long-awaited continental integration of Brazil, Bolivia, and Paraguay over the tracks of the Noroeste (ibid., pp. 26-7).

offer no clear indication of what he did to win voluntary acceptance of the medicine. In any case, to judge from his later report, the experience was unsuccessful: "For months, I evangelized, yet at the moment when the use of quinine was most necessary, everything that had been disseminated and taught proved a total loss" (pp. 189-91). As part of the same remarks, Neiva warned engineers and physicians that "such processes do not work with our people. I discovered this in Xerém and on the Noroeste" (pp. 189-91).

According to Castro, little was done by the Noroeste railroad to avert or combat the diseases that raged among workers (1993, p. 202). The initiatives of those responsible for prevention were constrained by the lack of medicine and resources, and they focused more on dealing with symptoms than on prevention. In fact, Neiva said his only commitment to the railroad was to "not allow deaths from paludism to rise" (1941, p. 158). He worked for the Noroeste for only ten months, that is, until mid-1909 (Fonseca Filho, 1974, p. 125). In May 1910, the railroad reached Itapura, on the border between São Paulo and Mato Grosso. In September, it reached the banks of the Paraná. Unhealthy conditions were such that the construction of a bridge over the river to replace the ferryboat was postponed until 1926. Few workers managed to reach that location alive or in good health. According to a director of the Noroeste, construction of the railroad took over 1,600 lives by 1909 (Castro, 1993, p. 197). Only in the 1930s did the tracks reach Corumbá.[23]

The vicissitudes that marked construction of the Noroeste do Brasil painted its history in the colors of an epic, exalted in the triumphalist literature: the civilizing mission of the railroad had been fulfilled despite all 'obstacles' (especially malaria), responsible for five thousand deaths, according to Senator Luiz Piza (Queiroz, 2004, p. 24). Neiva himself helped spread this ideology by praising the "ascending strength" of the citizens of the state of São Paulo, endowed with "remarkable energy [...] despite all the worms and malaria" (1927, p. 128). The cities planted along the banks of the railway would stand as testimony to the energy of the state where this sanitarian and politician from Bahia had spent a major part of his scientific career. It was Neiva who coined the phrase that best expresses the feeling of superiority among residents of São Paulo in the 1920s, when their state became the country's industrial leader: "São Paulo is a locomotive pulling twenty empty cars."[24]

Madeira-Mamoré Railway

Of all railroad ventures, the Estrada de Ferro Madeira-Mamoré was perhaps the most emblematic as far as the impact of so-called tropical diseases on the infrastructural works that supported modernization during this period of republican history. The shocking mortality rate among workers earned it the epithet "The Devil's Railway." Built between 1907 and 1912, it linked Porto Velho to Guarajá-Mirim, in the present-day state of Rondônia.[25]

In the mid-nineteenth century, Bolivia first expressed its interest in having a way to the Atlantic Ocean via the Madeira and Mamoré rivers and then the Amazon. As the largest branch along the Amazon's right bank, the Madeira riverbed is calm for 1000 kilometers, until it nears Santo Antônio, where a 400-km-long stretch of rapids begins on the slope of the central plateau. These waters originate in a river network flowing down the Andes. On the border with Bolivia, after the Guajará-Mirim waterfall, there begins a rough stretch of the Mamoré River into which the Beni flows farther down, along its left bank; from that point on, the river is known as the Madeira—meaning 'wood'—because of the many logs it drags with it.

In 1871, George Earl Church, of the US, acquired the concession to build the Madeira and Mamoré Railway, which would link the first waterfall on the Madeira River, at Santo Antônio, to Guarajá-Mirim. Works began in July 1872, but diseases, especially malaria, forced the company to pull out ten months later, before it had laid a single track (Ferreira, 2005, p. 83). Church put two other companies out in the field, in 1873-74, but the region's poor health conditions defeated them as well. In 1877, he hired P & T Collins (Ferreira, 2005, p. 121). Two years later, construction of the Madeira-Mamoré came to a halt. Of the 100 kilometers of track that should have been laid, only seven were in place. Some 450 to 500 people from the US, Bolivia, and mostly the Brazilian state of Ceará had died, recruited among those who flocked to the Amazon, driven out by drought and drawn by the rubber boom.

Following the War of the Pacific (1879-81), which pitted Chile against the forces of Peru and Bolivia, the latter country had to give up the province of Antofagasta to Chile, leaving Bolivia landlocked. The Brazilian government promised once again to build the Madeira-Mamoré, but the project would only be resumed following signature of the Treaty of Petrópolis, in 1903, which settled the issue of Acre, a territory belonging to Bolivia and occupied by Brazilian rubber tappers. Two years later, the speculator Joaquim Catrambi won a public bid to build the railroad (Ferreira, 2005, p. 193); he soon sold the concession to Percival Farquhar, of the US, who was the largest private investor in Brazil between 1905 and 1918, with interests in companies like Rio Light, Telefônica Brasileira, and a number of railroads controlled by the Brazil Railway. In the US, Farquhar founded the Madeira-Mamoré Railway Company and commenced works in 1907.

The starting point was moved to Porto Velho, seven kilometers from Santo Antônio. The 100-bed wood-framed Hospital da Candelária was erected on an elevation between the two settlements. At the height of construction works, in 1910 and 1911, eleven physicians served on the Madeira-Mamoré, four at the hospital and seven in the workyards. All top personnel (engineers, physicians, and technical specialists) were from the US. Earlier negative experiences led the Madeira-Mamoré Railway to bring in a steady flow of new workers, since the arrivals would fall ill within just two or three months, generally from malaria. They came from Central America (mainly the Antilles and Barbados), Europe, and Asia, and transformed the region into a cacophony of languages and cultures.

This turnover in the workforce was eventually hampered by the governments of Germany, Portugal, and Italy, which prohibited their citizens from being recruited; furthermore, the Amazon's rubber plantations were drawing people as well. There were two kinds of workers: contracted personnel and *tarefeiros*, or pieceworkers, the latter organized into groups and paid according to the task performed. The most vulnerable were those who opened trails, built the bed, or laid track and sleepers and who stayed overnight in temporary camps set up every ten kilometers along the line. The technical personnel were not immune from the "sickest railway in the world," in the words of Dr.

H.P. Belt, the first to head up the Madeira-Mamoré's medical service.[26] In his opinion, malaria followed a unique course there. It appeared in its most malignant form and seemed to be complicated by some factor unknown in other parts of the world (ibid., p. 229): "intense, pernicious anemia, rapid congestion of the liver, spleen, and stomach (the spleen and liver quickly grow to an enormous size), physical weakness and debility wholly disproportionate to the severity of the fever, swollen joints, and partial paralysis of motor and sensory nerves."[27]

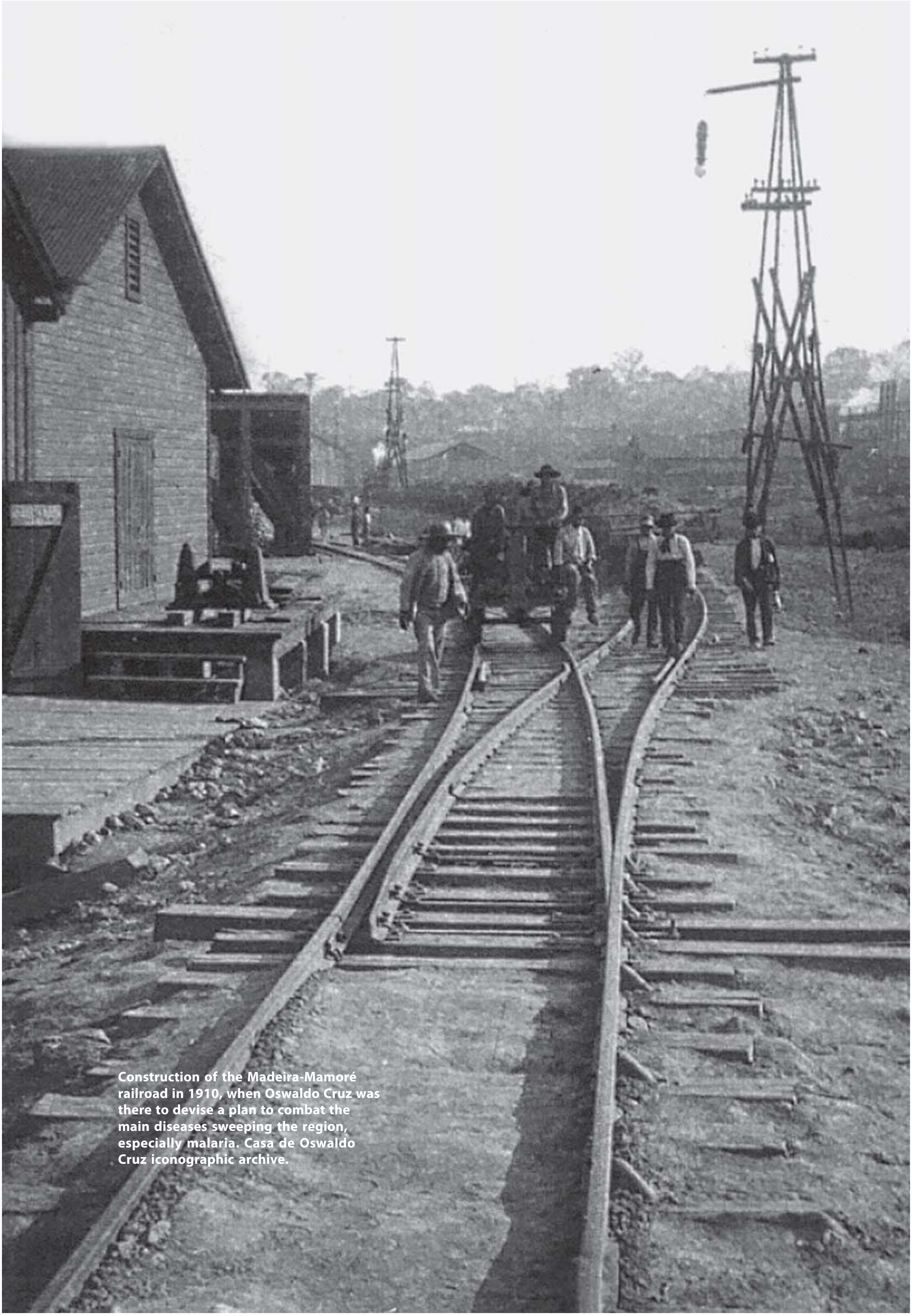
The damages caused by malaria and helminthiases were exacerbated by the high incidence of beriberi, whose etiology was still unknown at that time. We now know that it is an *avitaminosis*, which provides us with late evidence of the workers' deficient nutrition. In addition to hunger exhaustion, catarrhal cholangitis, pernicious anemia, brain congestion, and intestinal flu—all listed in Belt's diary—smallpox swept through in 1908 (ibid., p. 227). Along with the flu, it wiped out many Indians living in the region.

In a report to the Madeira-Mamoré Railway, Belt stated that he had never taken on an endeavor that demanded so much "organization and executive ability on the part of the medical body," which, in his opinion, should have a larger number of personnel, with experience in tropical diseases and trained in specialized institutions like the London or Liverpool School of Tropical Medicine (ibid., pp. 230, 231).

Carl Lovelace, who replaced Belt as head of the medical service, had taken part in the Spanish-American War in 1898 and had later worked on construction of the Panama Canal.

In 1910, the Madeira-Mamoré Railway Company hired Oswaldo Cruz in the belief that he possessed the knowledge needed to see this never-ending story through to a successful completion and that his prestige would help neutralize the criticisms the company had been receiving from the Brazilian and foreign press. Oswaldo Cruz and Belisário Pena boarded in Rio de Janeiro in June, soon after inauguration of the first, 90-km stretch of rail. They reached Porto Velho on July 9, 1910, remaining there for 28 days.[28] In September, Cruz presented the company with a report on the observations underpinning the advocated measures. He examined the environmental characteristics of the Madeira and Mamoré rivers. Natural history and ecology were indispensable to an understanding of the local nosographic picture, which formed a tangled web of humans, pathogens, and vectors associated with the local fauna and flora. The regime of the waters in this hydrographic complex favored the presence of "torrents of mosquitoes"—transmitters of malaria—with periods of flooding following periods of low waters, which occasioned the formation of swamps and pools (Cruz, 1972, p. 571). According to Oswaldo Cruz, the lower Madeira was a healthy river but its tributaries were not (p. 568). In addition to the annoying insectivorous fauna and poisonous plants and animals, human habits contributed to the seriousness of diseases: that is, the rubber-tappers' terrible diet and the sanitary conditions in Santo Antônio, which had no sewer or garbage collection system, where pools of water stood in potholes, carrying the malaria infection to everyone in the settlement, "without exaggeration" (p. 574).

Oswaldo Cruz praised the company for settling its personnel in Porto Velho, which then had 800 inhabitants, for equipping the city with water and sewer, and for building



Construction of the Madeira-Mamoré railroad in 1910, when Oswaldo Cruz was there to devise a plan to combat the main diseases sweeping the region, especially malaria. Casa de Oswaldo Cruz iconographic archive.

houses in high spots, protected against mosquitoes (1972, p. 581). The Hospital da Candelária boasted the facilities and equipment of an urban hospital—including a pavilion for the isolation of those with tuberculosis or yellow fever—plus four physicians, who Cruz believed to be skilled in clinical and laboratory exams (p. 587). According to the scientist, of the eleven physicians, five had acquired experience in tropical diseases during construction of the Panama Canal.

In Cruz's description of the work system, we can note a discrepancy between the living conditions of the higher-ranking personnel and of the workers, who resided in rudimentary camps along the line. Oswaldo Cruz divided the observed diseases into cosmopolitan and tropical. Among the first group, pneumonia, which had a high mortality rate, was noteworthy, as was measles, introduced by a ship in 1910. In the second, besides malaria, ancylostomiasis was very common (found in over half the laborers), along with beriberi, dysentery, hemoglobinuric fever, as well as "occasional tropical diseases," like yellow fever, Madura foot, pinta fever, espundia, and calazar.

The diversity of diseases notwithstanding, paludism was the main culprit behind the unhealthy conditions on the Madeira-Mamoré. It was its prevalence that turned the relation between normal and pathological upside-down: the population "has no idea what good health is," according to Oswaldo Cruz (1972, p. 607). Morbidity was tremendously high but mortality much lower. The most prevalent clinical form was the most serious: autumnal or tropical (70%), caused by *Plasmodium falciparum*.

Given the costs involved, Oswaldo Cruz discarded straight away the "definitive sanitation of the zone" through the drying up of swamps, rectification of rivers, elimination of water-storing plants — in short, the enforcement of neutralization initiatives where malaria transmitters bred. As with Chagas and Neiva's campaigns, all emphasis was placed on the use of quinine and protection against mosquito bites. But in this particular context, Oswaldo Cruz felt the already high doses used in Xerém and Minas Gerais would prove inefficacious, and he proposed a daily application of two to three grams!

Neiva had observed quinine's decreasing effectiveness against malaria in Xerém. In a paper published in *Memórias do Instituto Oswaldo Cruz* in 1910, he presented the theory that quinine-resistant breeds of plasmodium were able to develop thanks to the parasite's ability to adapt to environments with different alkaloid contents. In his report to the Madeira-Mamoré, Oswaldo Cruz endorsed this viewpoint but noted that a daily dose of more than 0.75 to 1 grams of quinine caused signs of toxicity. The scientist had observed extremely resistant cases: some of the ailing still had parasites in their blood 24 hours after a 6-gram intravenous dose of quinine. German patients were sent to the hospital at Hamburg's Institute for Maritime and Tropical Diseases, where Bernhard Nocht and Heinrich Werner confirmed the exceptional resistance of the hematozoa. In an article likewise published in 1910, they released their conclusion that the resistant strains developed during the parasite's endogenous cycle, in other words: in man and not in the mosquito, as Neiva argued.

In his report to the Madeira-Mamoré, Oswaldo Cruz applauded the free distribution of quinine and the fact that mosquito netting was provided to the laborers; he also expressed his opinion that the workers continued to fall ill "only because, out of ignorance,

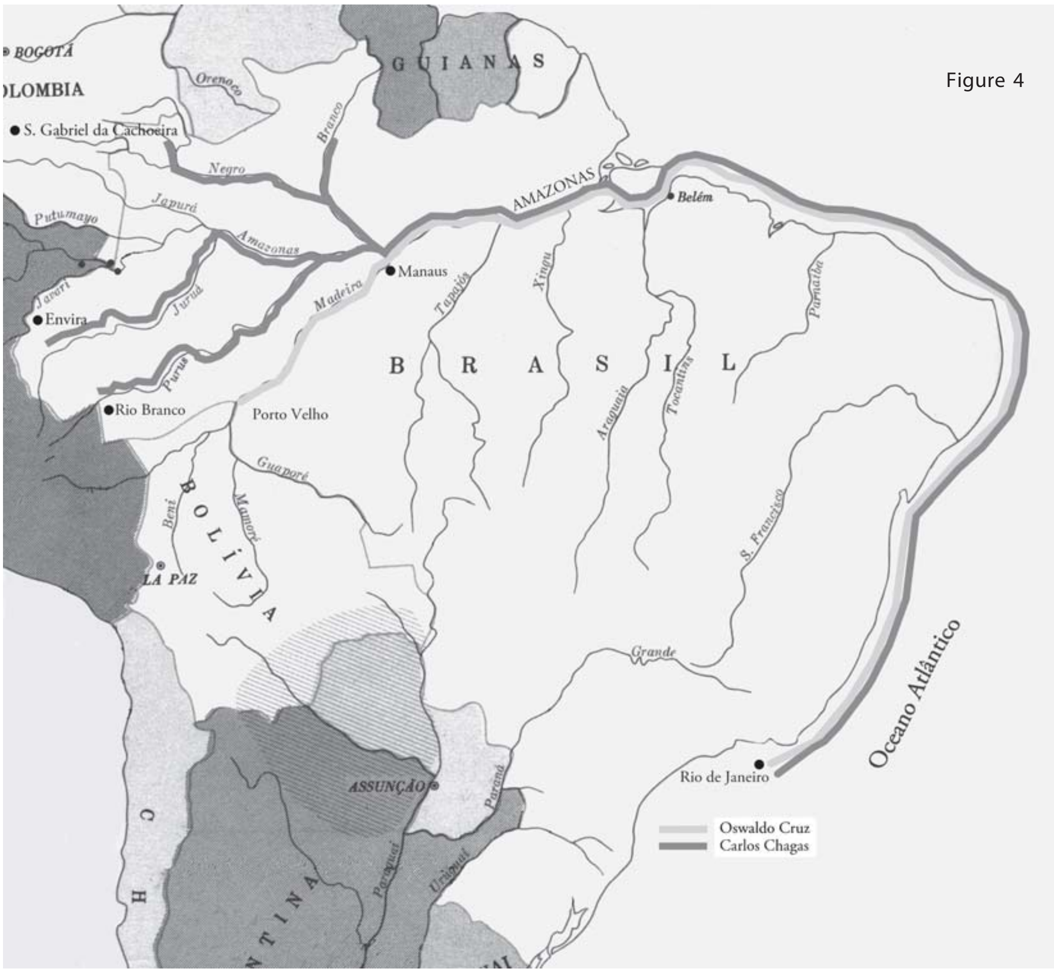


Figure 4

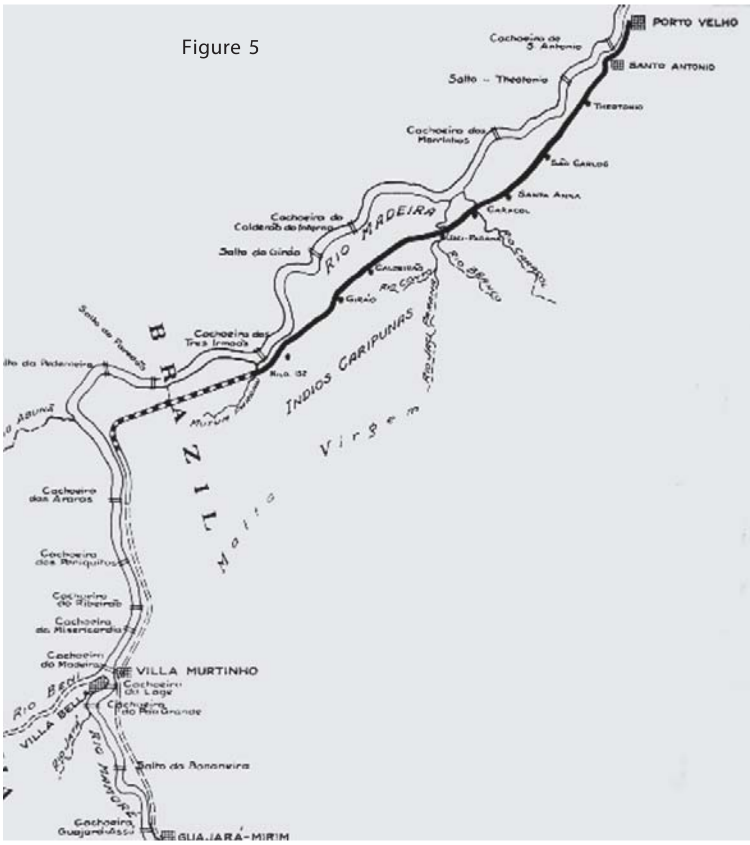


Figure 5

Routes traveled by Oswaldo Cruz and Carlos Chagas in the Amazon. At the service of the Madeira-Mamoré Railway Company, Oswaldo Cruz and Belisário Pena embarked in Rio de Janeiro in June 1910, shortly after the first stretch of track had been inaugurated, reaching Guajará-Mirim in the present-day state of Rondônia (shown on the smaller map). Soon after the April 30, 1912 inauguration of the Madeira-Mamoré, Carlos Chagas began his expedition under a contract between Oswaldo Cruz and the Superintendence of Defense of Rubber, which was endeavoring to forestall a crisis in this important sector of the Brazilian economy. From October 1912 through March 1913, Carlos Chagas, Pacheco Leão, João Pedro de Albuquerque, along with a photographer, visited much of the river network where rubber extraction took place. They first left Manaus, traveling up the Solimões River and its branch, the Juruá. They returned to the capital of the state of Amazonas and on December 2, 1912, headed out on the Purus River and its branches (Acre and Yaco), along whose banks the Amazon's most prosperous rubber stands were found. On February 6, 1913, they made their last trip to the Negro River and its branch, the Branco, going as far as the waterfalls near the border with Venezuela.
Figure 4 – *Atlas Histórico Escolar – MEC*. Rio de Janeiro,
Departamento Nacional de Educação, p.56. 1960.
Figure 5 – available at: http://www.culturasampa.blogger.com.br/mapamadeiramamore.jpg

carelessness, or stubbornness, they did not comply with the determinations of the company's sanitation corps" (ibid., p. 619). According to Lovelace, "the bias against quinine was so great that it was very hard to compel a man infected with malaria to take enough of this drug."[29]

Before moving on, we should alert the reader to certain facts that may lie hidden within this interpretation, facts about the side effects of ever-greater doses of quinine—just a hint of something that merits further analysis. In the literature we consulted, we found interesting suggestions that somewhat undermined the view of Oswaldo Cruz and his peers, which was an interpretation that in fact bore similarity to the one put forward shortly before to explain the revolt against the mandatory smallpox vaccine in Rio de Janeiro (1904).

In the campaign in Xerém, where reactions to mandatory quinine were apparently more violent, a number of engineers resisted taking it, alleging that it caused great discomfort and attacked various organs, "starting with the stomach, with its prolonged use triggering profound disturbances in the organism, for it even acted as an anaphrodisiac" (Neiva, 1941, p. 170). Sampaio Correia himself, the engineer that hired Neiva in Xerém and then, later, on the Noroeste railroad, had an aversion to the medicine because it caused him "serious disturbances" (p. 172). Ringing in the ears, tremors, and nausea were common complaints. At the Hospital da Candelária, Oswaldo Cruz observed a patient who was cured of malaria after taking about 20 grams of quinine in eleven days, but the man also ended up blind. He likewise heard the story of an Indian timber-cutter who received this same amount of quinine and was told to take 60 cg of it a day. The native misunderstood the instructions and took all 20 grams at once. He was found wandering about the forest, deaf and blind, and these problems lasted for some days (p. 180).

Oswaldo Cruz proposed to the Madeira-Mamoré Railway that they adopt a regimen similar to that used by Neiva, Chagas, and Pena in Xerém and Minas Gerais (1972, p. 620). The quinine distributor would give workers a certificate stating they had taken the medicine, and the men would not be paid unless they could show the paper; any days they had not taken it would be deducted from their wages. They would be rewarded every month in which there was no case of malaria in their group, as would workers who managed to keep healthy for three months. At the end of the workday, those responsible for administering quinine had to see that personnel went back to their screened lodgings and stayed there. Any refusal to use mosquito netting after dusk could also mean wages would be docked. Physicians were to give all personnel blood tests three times a week and check the conditions of mechanical mosquito protection methods. Workers suffering from malaria should be treated "forcefully" and whoever was responsible for the medical service had "discretionary power" to dismiss any personnel who resisted prophylactic measures, whatever the employee's job position (p. 623).

Oswaldo Cruz recommended that workers with chronic paludism not be hired and that anyone who had not been "microscopically cured"— in other words, individuals whose blood still presented parasites—should be banned from the line (ibid, p. 616).

We do not know to what extent these suggestions were embraced by the Madeira-Mamoré Railway. One source says that they reduced malaria cases from 40% to under 10%

and deaths from 15% to 2% (Sousa, 1926, p. 226). According to Ferreira, the number of deaths remained high, and the company kept in place its practice of steady replacement of workers (2005, p. 283).

A new stretch of line was opened on October 30, 1910, with a second one opening in September 1911, bringing the track to 220 kilometers (Ferreira, 2005, p. 283). Of the 5,664 men brought in that year, 419 died, 51 from malaria. Morbidity was 5,019, of which 4,968 were pronounced cured (p. 285).

Covering 364 kilometers between Porto Velho and Guarajá-Mirim, the Madeira-Mamoré was inaugurated on April 30, 1912. Its profitability was soon to be shaken by the crisis that hit the Amazon's top export: rubber. Boasting a more productive, rational form of organization because of the British and Dutch, the rubber plantations of Ceylon, Malaysia, Sumatra, Java, and Borneo soon reached Brazil's level of production. The railroad in fact started up operations the last year that Brazilian rubber output surpassed that of the Orient's. This was the same year that the Madeira-Mamoré Railway presented the Brazilian government with the final bill on construction of the railroad—in money and in lives. Of the 21,817 workers hired, 1,552 died at the Hospital da Candelária. This figure does not, however, include those who passed away somewhere along the track, those who were not contracted (pieceworkers), and those who died in some hospital in Belém, Manaus, or perhaps their native countries. Ferreira estimated the total number of deaths at 6,208 (2005, pp. 301, 302).[30]

Malaria in the context of endemic rural disease

In 1912, Congress approved the Rubber Defense Plan (Plano de Defesa da Borracha) and founded the agency that would enforce it. In addition to providing for the modernization of rubber tapping, processing, and marketing, the plan included sanitation measures to hold "the absurdly high mortality rate within normal limits."[31] From October of that year to March 1913, Carlos Chagas and a team journeyed via river over much of the area of extractivist activities in the Amazon. Around the same time, other Instituto Oswaldo Cruz expeditions were traveling through Central and Northeast Brazil at the service of the E.F. Central do Brasil and mainly of the Inspetoria de Obras Contra as Secas, a drought-fighting agency created in 1909. The longest of these expeditions, by Arthur Neiva and Belisário Pena, covered some 7,000 kilometers from March to October 1912, through the states of Bahia, Pernambuco, Piauí, and Goiás.

Amazon's rubber crash was irreversible, and the 'Republic of the Colonels' neither could nor wanted to address the longstanding tragedy of drought in the Northeast. Still, these physician-sanitarian commissions equipped the Instituto Oswaldo Cruz and other Brazilian institutions with a valuable set of observations and material on malaria and on the still unknown universe of rural endemic diseases. Rich in sociological and anthropological observations, the expeditioners' reports had big repercussions in Brazil's large coastal cities and helped arm debates on the national question, then being reframed from a longstanding perspective in Brazilian social thought: the dualist vision (Lima, 1999). Following reform of the capital of the Republic, the vainglorious exaltation of Brazilian 'civilization' was silenced by corrosive revelations about the 'other' Brazil, wretched and sick.

When Oswaldo Cruz passed away on February 11, 1917, he left behind an internationally recognized institution and a combative generation of sanitarian-scientists. Under the leadership of Carlos Chagas—Cruz's successor as head of the institute from 1917 until his own death in 1934—and of the relentless political journalist Belisário Pena, these doctors, arm in arm with other social groups, fueled a strong movement for the modernization of health services, under the flag of "valuing man and earth."[32] This movement, which took place during World War I, was one sign of the crisis of legitimacy undermining the political edifice of the First Republic, a crisis that would worsen the following decade. The ruling oligarchic bloc gave in to some of its grievances. On May 1, 1918, at the end of his term of office, President Wenceslau Brás signed a decree creating the Rural Prevention Service (Serviço de Profilaxia Rural) and granting Belisário Pena 1,000 contos to multiply the public health posts he was setting up on the outskirts of Rio de Janeiro. The Sanitary Code drawn up by Arthur Neiva,[33] director of the São Paulo State Sanitary Service (Serviço Sanitário do Estado de São Paulo) since December 1916, was the first to wholly incorporate the rural sanitation program. According to Castro Santos, large rural landowners' resistance to public initiatives within their domains lessened during the war, among other reasons because declining foreign immigration encouraged them to place greater value on the length of the useful lives of members of their workforce (1987).

On March 1, 1918, Rodrigues Alves, who sanitized the federal capital, was re-elected president of the Republic. On the eve of his November 15 swearing-in ceremony, however, the Spanish flu struck him down, and vice-president Delfim Moreira stepped into office. Survivors of the influenza and of the European war that had come to an end with the signing of the Armistice on November 11 celebrated the arrival of the new year euphorically. In July 1919, the new president-elect, Epitácio Pessoa, took his oath of office in Rio de Janeiro. As Pessoa was a representative of Paraíba—a peripheral state within the oligarchic pact that governed Republican politics—and a relative of Carlos Chagas as well, the sanitation movement came out ahead. In January 1920, the National Public Health Department (Departamento Nacional de Saúde Pública) came into being; the appointment of Chagas as director—a post he would hold until 1926—strengthened the strong bonds between the Instituto Oswaldo Cruz and public health, now better equipped and enjoying greater autonomy.

The Official Medications Service (Serviço de Medicamentos Oficiais) began functioning at this institute and at Butantan. Its task was to prepare substances for use in treating malaria, ancylostomiasis, Hansen's disease, Leishmaniosis, and syphilis. Quinine pills were made available free of charge to Rural Prevention posts and supplied at subsidized prices to states, the Armed Forces, and government and private enterprises, including railways, which were supposed to provide their workers with this malaria prophylactic at no cost.

Following the outbreak of WWI, the periodical *Memórias do Instituto Oswaldo Cruz* quit publishing its paper in both Portuguese and German, the latter substituted by the language acquiring hegemony: English. The war made room for the US to move into the markets and territories controlled by the British in the Caribbean and Central America and expand its influence beyond this section of the continent. In Brazil, the campaign for rural sanitation and public health reform coincided with the establishment of the International Health Board, maintained by the Rockefeller Foundation.

Malaria was the third disease that the Rockefeller Foundation went after on a global scale. The campaign against ancylostomiasis, begun in the southern US in 1909, had moved to the world stage in 1913. As both Stapleton (2004, pp. 206-15) and Cueto (2007; 1996, pp. 179-201) have shown, this target had been chosen because a rapid cure was possible by administering antihelminthics to expel the worms. Its victims were usually rural workers incapacitated by the disease, which was much in the public eye thanks to images like Jeca Tatu, a figure created by writer Monteiro Lobato and inspired by the sanitation movement. The successful yellow fever campaigns in Cuba, Panama, Rio de Janeiro, and Belém showed that it was possible to vanquish the epidemics then receiving much public attention, which could finally be linked to a clearly identifiable vector.[34] Furthermore, the 1918 identification of its supposed agent by Hideyo Noguchi of the Rockefeller Institute for Medical Research reignited the hope for an effective vaccine.

Malaria was not such a sure candidate for success. Outbreaks on European and Middle-Eastern battlefields had shown it could gain epidemic proportions in the northern hemisphere. But malaria did not have the dramatic nature of yellow fever; many people in fact lived with it for years. Its etiology was still complex and the chances for a vaccine nil. Age-old knowledge of quinine's effect was shaken by evidence of the hematozoan's resistance. Strategies were initially deduced from the fact that *Anopheles* was the genus in which the external cycle of the *Plasmodium* took place. However, they grew more complex as the number of identified species rose and it was recognized that they all had quite distinct habits and varying abilities to transmit the disease, thereby requiring specific actions in accordance with each region's ecosystem.

The theory of domiciliary infection on the agenda

The International Health Board (IHB) launched its anti-malaria initiatives in 1915 in some rural counties of Arkansas and Mississippi. By 1923, it was also active in Nicaragua, Puerto Rico, El Salvador, the Philippines, and Palestine. In Brazil, a team headed by Mark Boyd began its activities in June 1923, in malarigenous areas of the Baixada Fluminense, Rio de Janeiro state. Four months later, Carlos Chagas proposed to Boyd and to the Rockefeller Foundation's representative in Brazil, George K. Strode, that a field research study be undertaken to prove the theory of domiciliary infection. "Dr. Chagas is so convinced that his idea is going to revolutionize the methods currently in use […] that he probably won't accept any negative results," Strode wrote to F.F. Russell, director of the IHB, on January 15, 1924.[35] In Strode's opinion, if they were to take this project on, it would have to be broad enough to either prove or invalidate Chagas's theory; Boyd, however, did not want to get involved in this investigation, since negative results might leave a bad impression. One week later, Russell advised the representative of the IHB's final decision.[36] A then recently completed study by M.A. Barber showed that anophelines did not remain inside a house for more than two days after feeding on blood. What was known about the species found in the southern US tended to confirm the idea that they scattered quickly. Boyd and his team would conduct observations in Brazil to diminish doubts in this regard. Francis Metcalf Root was made responsible for entomological studies.

According to Deane (1988), his most important accomplishment was describing *Anopheles* (*N.*) *darlingi*, the most efficient malaria vector in most of Brazil, which until then had been confused with other species. Nothing indicates a return to the questions of interest to Chagas.

Echoing the yellow fever approach, the US priority was to attack mosquito larvae. The validity of this strategy was reinforced in the early 1920s when it was shown that Paris green was a more efficient larvicide than previous methods, in which petroleum was sprinkled on standing waters.[37] As Williams has shown (1994, pp. 23-51), when the Foundation took the helm of the yellow fever campaign in Brazil, it had serious skirmishes with Brazilian sanitarians who were faithful proponents of Oswaldo Cruz's method of spraying houses to rid them of winged mosquitoes—a method likewise defended by politicians who saw electoral advantages in these 'spectacular' initiatives.[38]

On June 4, 1924, Chagas was informed of the IHB refusal to test his theory. "He was, of course, disappointed," wrote Strode, "but he's so firmly convinced of the feasibility and success of the plan that he is preparing to carry out the research through the Instituto Oswaldo Cruz."[39]

As mentioned earlier, the theory that led Chagas to place eradication of adult mosquitoes inside of housing units at the top of his list of malaria prophylactic measures was announced shortly after the Itatinga campaign. In articles published subsequently, Chagas continually defended this theory; in actual fact, however, he had to abandon it or relegate it to a secondary plane, instead mainly favoring mass administration of quinine to personnel recruited by railroad companies. There was thus a discrepancy between his discourse as a scientist addressing his peers and his pragmatic stance as a sanitarian, striving to reach goals established by his clients in the shortest time and at the lowest cost.

In terms of malaria, the practical measures derived from this theory were almost identical to those that Oswaldo Cruz had employed against the yellow fever transmitter in Rio de Janeiro, that is, destruction of mosquitoes inside of housing. It is quite possible that observations on the domiciliary habits of *Stegomyia fasciata* influenced Chagas's view regarding the very diverse environments in which malaria was caused by mosquitoes. At that point, little was known about these insects and he, Neiva, Cruz, and Lutz were just starting to identify them.

Chagas's first reference to the domiciliary destruction of winged *Culicidae* came in an article published in *O Brazil-Medico* in 1906-07 ("Destruição domiciliária dos culicídios alados"). The Itatinga finding that the infection was much more common inside housing than outside was likely influenced by Chagas's reading of a "recent, interesting article by Ruge," a physician with Germany's Navy General Staff, in which the latter explained "apparently contradictory facts in the current transmission theory, such as, among others, the absence of mosquitoes and the existence of paludism epidemics in seasons with constant low temperatures" (Chagas, 1906-07, pp. 16/23). Chagas did not say to what article by Ruge he was referring. At the October 1, 1926 conference of Rio de Janeiro's Society of Medicine and Surgery, Dr. Eugenio Coutinho attributed the first statement about the prime role that housing played in the spread of malaria to the Italian B. Gosio. Whatever the theory's origin, it gained shape and density thanks to Chagas's observations in the interior of Brazil, which compelled him, in the scientific papers he published at that time, to defend the idea that eradicating mosquitoes inside of houses might be the only prophylactic method—or at least the cornerstone of an anti-malaria campaign. The theory changed little in structure during those years.

According to Chagas, hunger would drive anophelines into houses. After filling themselves on the occupants' blood, the insects would lie about lazily, generally in dark corners, digesting their food and waiting for their eggs to mature. They would often stay inside these houses for days on end, especially when the temperature outside was less favorable. Since they would not lay eggs because it was hard to find suitable deposits of water, and since they did not breed, these anopheline could most likely live longer. This longevity would give the malaria hematozoan enough time to complete its life cycle inside the mosquito. So the fact that they stayed inside of dwellings facilitated the infection of people, through repeated bites. According to Chagas (1906-07, pp. 16-23, 1908, pp. 4-8), the proportion of contaminated anophelines was higher inside than outside not only because they lived longer but also because they fed solely on human blood, while insects on the outside would also feed off animals and die early more often, before the parasites they were hosting could complete their life cycles.

In the paper he presented at the Sixth Brazilian Congress of Medicine and Surgery, in September 1907, Chagas was even more emphatic on this point: malaria was almost exclusively a domiciliary 'contagious' disease.

> For anophelines in the outdoors, especially those inhabiting woods lying far from human housing, rare are the opportunities for contamination or to play a role as a transmitter; because outside of dwellings, man is usually in movement. […] And the anophelines that are contaminated, during the few opportunities offered to them […], are subject to a thousand chances for death and to being scattered through space, making the percentage of those infected extremely small (Chagas, 1908, p. 8).

Chagas then stated that he was seeking to ground these ideas experimentally. If he could do so, prevention of paludism would be greatly simplified: it could be limited to periodic expurgation of housing, every six to eight days, in order to eliminate the contaminated anophelines before they themselves could contaminate. All other methods could be abandoned, including preventive administration of quinine, the mainstay of campaigns carried out for railroad companies. "The economic and practical ease of this method is clear […]; it would, over the administration of quinine, for example, have the advantage, among others, of eliminating the factor of individual will" (Chagas, 1908, pp. 4/8).

In the 1920s, Chagas needed to produce more robust experimental proof to win over malariologists, at a moment when nations, colonies, and international health agencies were beginning to organize and coordinate previously isolated anti-malaria initiatives and to review accepted strategies in light of recognized failures. Chagas's theory was presented once again, this time at the First International Malaria Congress, held in Rome in October 1925 (Chagas, 1926, pp. 167-72).[40] There Chagas stated that Alcides Godoy's observations on the two main malaria transmitters in Brazil (*Cellia argyrotarsis* and *C. albimana*) lent experimental bases to the thesis that the disease was by nature almost solely domiciliary.

Something should be said about this peculiar association. Godoy had joined the Instituto Oswaldo Cruz in 1903, devoting himself to bacteriological studies and the development of vaccines. He was not familiar with entomology. The experiences reported by Chagas were not published in *Memórias do Instituto Oswaldo Cruz* and all indications are that they remained unpublished. Together with entomologist César Pinto, Godoy published an article in *Brazil-Medico* (1923) in which he reported on their work against malaria in Campos, along the Muriaé River; however, the conclusions—presented prior to Chagas's efforts to engage the IHB—endorsed the domiciliary theory only in part.

The crux of Chagas's presentation at the 1925 Congress is found in facts about the mosquito's laying habits, through which it satisfied the primordial demand to "perpetuate the species." Godoy provided him with the evidence needed to affirm that in Brazil the main malaria transmitters generally died soon after laying eggs the first or second time—in other words, in a shorter interval than what would be necessary for the disease parasite to complete its sexual evolution. Egg-laying thus constituted a decisive obstacle to the exogenous life cycle of the hematozoan. Only those mosquitoes whose breeding could be delayed by their remaining inside could become infected. Terms like "most of the time" and "generally" pepper the postulate with enough grains of doubt, and Chagas actually warned: "it is possible that, in the case of other species of anophelines, and under special epidemiological conditions, events transpire differently" (1923, p. 168).

His experience in Brazil's malaria zones had shown him that there were always a great number of malaria-transmitting mosquitoes inside of houses. Godoy had honed this datum: the number was always larger at night, which meant that part of the insects escaped at dawn. During the night and early in the morning, they were generally active, voracious, and flew quickly. Late in the day, they seemed to grow lazy, make shorter flights and, when pursued, simply move to another spot. When mosquitoes captured during the first period were dissected, it was discovered that their ovaries had not yet developed; those captured during the second period displayed complete development of their ovaries. Godoy's and Chagas's conclusion was that part of the mosquitoes that enter housing at night escape in the morning, dying soon, either because they are destroyed or, especially, because they lay their eggs earlier, so the life cycle of the hematozoan is not completed in these mosquitoes. Another portion of them remain inside and feed off the blood of animals or man. As their ovaries develop, they gain substantial weight, which would account for their sluggishness or immobility. Therefore, these mosquitoes stay inside for mechanical reasons, until their breeding instinct forces them outside in search of water. They are the infective agents.[41]

Other epidemiological deductions by Chagas legitimized the domiciliary theory: in endemic regions, very young children—including infants—always had a higher splenomegaly rate than the adults, since the former spent more time inside. This was a two-way argument: since mosquitoes were the main reservoirs of the hematozoan, the longer they stayed inside, the greater their chances of being infected. If the disease were picked up outside, in the vicinity of swamps, rivers, and other places where mosquitoes bred, the highest rates of infection would be found among adults.

In practical terms, as mentioned earlier, the domiciliary theory required the systematic, periodic destruction of anophelines inside of housing units, so that the parasite could not complete its exogenous cycle and the mosquitoes that escaped mechanical protection measures would remain inoffensive (Chagas, 1906-07, pp. 20/23). Both measures were enforced in Itatinga.[42] At the 1925 Congress, while Chagas did not argue against the importance of protecting housing units, he did point out that one often ran into insurmountable obstacles in poor rural zones, where few could afford what the method demanded. Burning sulfur inside of houses every eight or ten days would suffice to squash the epidemic outbreaks of the disease. Even with doors, windows, and other vents left open, the method would be enough to eradicate the infection from homes: the mosquitoes not killed by the sulfur would flee outside, where they would no longer pose a measurable concern in the spread of the epidemic (Chagas, 1926, p. 170).

Compared to the ephemeral campaigns previously conducted for railroad companies, Chagas's new emphasis on rural housing was quite novel in combating malaria. In some regions of Brazil—he did not specify which—"special types of housing" designed by Godoy had been adopted. Chagas does not describe the features of this housing, save the fact that dwellings were oriented so the wind would help keep mosquitoes at bay.

According to Carlos Chagas Filho (1993, p. 78), the Congress in Rome recognized the importance of the theory espoused by his father, but it was only fully efficacious after the use of DDT became widespread in combating malaria, in the 1940s. The Congress annals, however, bear witness to controversies surrounding Chagas's ideas. Then-recent studies by the Paludism Commission, which was part of the League of Nations Hygiene Committee, seemed to confirm the anopheline's domiciliary habits and the suspicion that houses would be the prime locus for the disease. Based on observations from eastern Africa, in 1902, Émile Brumpt argued that the infection could be caught in the open air. This danger would remain "the object of discussion for quite some time," he stated, especially if the expression 'open air' were to include the shelters of peasants and shepherds (Chagas, 1926, pp. 175-6). Sydney Price James, who had observed a homing instinct in anophelines, disagreed with Brumpt: "This issue must be addressed mathematically. We thus reach the conclusion that it does not matter how many mosquitoes there are; the number that bites is infinitesimally small, and you can walk in the open air your whole life through without ever catching malaria (ibid.)."

This comment by Neiva gives us an idea of just how much disagreement there was: "I protest most categorically against reassuring information that anophelines of Brazil remain inside houses," he wrote in 1925.[43] This sentence resonated at a tumultuous moment in the professional lives of Brazilian physicians working in public health, medical clinics, and experimental medicine (Benchimol and Teixeira, 1993), which may explain why Godoy was the scientist Chagas called on to provide the experimental data he needed. For Neiva, a well-regarded entomologist, whether or not the anopheline stayed inside depended upon its species and the place. In an article published in 1940, shortly after the campaign against *A. gambiae*—that is, against a 100% domestic strain (Deane, 1985, p. 90)—Neiva indicates his surrender to the domiciliary theory: "Paludism is usually caught inside a dwelling, of whatever type." Curiously, it was a railway that led him to this counter-example: "Cases are cited of people who spend their summers in [the mountain city of] Petrópolis and then catch paludism when their train passes through the Baixada and mosquitoes come into their cars. Such cases, I have heard, are rare" (Neiva, 1941, pp. 192-3).

Combating mosquitoes inside of dwellings and using quinine and its successors became the pillars of anti-malaria campaigns from then on, including the unsuccessful one that was meant to wipe the disease off the planet.[44] Yet during a 1985 debate, an argument was voiced that most certainly can still be heard: “We believe that the transmission of malaria is basically domiciliary. However, in the Amazon region […] this principle does not hold because the type of housing—without walls—[…] does not shelter people […and] there is no place to put the insecticide” (Tauil, 1985, p. 72).

Final considerations

The railroads were powerful symbols of the ideals of progress and civilization advocated by the elites of the period in question. As such, these transportation projects were objectively in an excellent position to contribute to expanding domestic and foreign markets, bringing the territory together, and subordinating people of the interior to the government and to the hegemonic centers of Brazil’s capitalist society. Malaria was simultaneously an obstacle for railroads and other ventures aimed at modernizing society under the First Republic, as well as a product of the impact this society had as it went about devastating different ecosystems.

Seen from the perspective of the campaigns of greatest scope, conducted from the 1940s on, the initiatives carried out between the 1890s and 1920s to protect railroads, hydroelectric plants, and agricultural projects seem merely isolated, disconnected, and inexpressive. Because of this, we still know little about the history of malaria in Brazil during this time, with the work of Stepan representing a possibility of things to come (2003, p. 26). We have explored some of the initiatives taken back then and have shown that they were relatively effective in reaching proposed goals. We have also shown how they acted as catalysts in making important progress in knowledge of the disease and of the medicine then called “tropical.” The narrative we have followed up through the 1920s depicts energetic growth in theoretical and technical innovations and illustrates the ever-tighter relations between institutions and professionals around the world who shared their experiences, often clashing with the standards set out under the prevailing paradigm. Much is still left to be done regarding the circulation of ideas, innovations, successes, and failures by these institutions and professionals. There is also much to be done in exploring the synergy between research and practice in malaria and the other diseases to which both protozoology and medical entomology have laid claim.[45]

We left Carlos Chagas’s theory of domiciliary infection for last because this was an innovation that linked two well-defined phases in the history of malaria control: it was conceived in a railroad workyard but did not fit in with this type of campaign; the theory was relaunched at a moment when continuous, ongoing initiatives against this and other endemic diseases were being drafted but still assigned a marginal role. While we have raised some hypotheses, the final explanation awaits further studies.

The domiciliary theory, the theory that quinine-resistant breeds emerged, and other ideas and solutions then proposed enrich our understanding of how knowledge is produced, received, and disseminated in societies that are considered subaltern or peripheral to the so-called centers of civilization.

For a long time, Brazil's intellectual and scientific tradition was considered basically imitational. In this case, as in others recently studied by historians of science, we have seen how Brazilian sanitarian-scientists were co-participants in blazing the frontier in diverse fields of knowledge, devoting all their creativity to balancing relations that are actually profoundly unequal. The fact that these efforts and creativity were not recognized by institutions and scientists from hegemonic countries in the past or by the historiography now produced by these same countries is a constitutive part of the asymmetries of the world in which they lived and in which we continue to live.

NOTES

[1] The creation of these two schools coincided with the intensification of the dispute between the English and the Italian over priority in the discovery of how malaria is transmitted to humans. "It is *indispensable* that we be at the front on the practical side of the mosquito theory; otherwise, Grassi will develop it," Ross wrote to Manson on June 14, 1899 (cited in Bynum and Overy, 1998, p. 407). At the same time, the British medical field was jolted by the constitution of tropical medicine as an autonomous discipline. For more on this, see Worboys, 1976, 1993, 1996.

[2] We now know that malaria is caused by three species: *Plasmodium vivax*, responsible for benign tertian; *P. malariae*, for quartan; and *P. falciparum*, which causes the most serious form of the disease, known in the early twentieth century as tropical malaria, acute tertian fever, or estival-autumnal fever. Some included the agent of 'tropical malaria' in another genus: *Laverania*. In addition to the three species identified by Golgi, we now know of *P. ovale*, which is found only on the African continent.

[3] For more on this, see Howard (1930); Smith, Mittler, and Smith (1973); and Benchimol and Sá (2006).

[4] For more on this, see Benchimol and Sá, 2005, pp. 43-244; 245-457.

[5] On Sep. 13, 1946, the São Paulo Railway was expropriated by the Brazilian government. Two years later, it was rechristened the Estrada de Ferro Santos-Jundiaí and later became part of the Rede Ferroviária Federal S.A. For more on this, see "Empreendimentos que honram o Estado de São Paulo," in *O Diário*, Jan. 26, 1939; Santos and Lichti, 1996.

[6] It was republished on Apr. 30, 1950, by the *Revista Brasileira de Malariologia*, v. II, no. 2, in Portuguese ("Mosquitos da floresta e malaria silvestre," pp. 91-100) and in English ("Forest Mosquitoes and Forest Malaria," pp. 101-10). Lutz's paper was again republished, in all three languages, in Benchimol and Sá, 2005, pp. 731-68.

[7] Adolpho Lutz attached to the dissertation, which was published in 1904 by a modest print shop in Bahia, a lengthy study of his own authorship entitled "Synopse e systhematisação dos mosquitos do Brasil." Both were republished in Benchimol and Sá, 2006.

[8] Available at www2.prossiga.br/Ocruz/textocompleto/dosRochalink1.htm.

[9] Among their arguments, those who were not convinced pointed to the fact that other vectors or means of transmission had not been excluded experimentally. For more on this, see Benchimol (1999). Despite his identification with Oswaldo Cruz's 'party', in 1903 Lutz wrote that forest mosquitoes could also transmit the as-yet unidentified yellow fever germ, a hypothesis that was confirmed in Brazil in 1932 by Fred Soper (1933) and his team, from the Rockefeller Foundation.

[10] On Chagas, see Chagas Filho (1993) and Kropf (2005, 2006).

[11] On Neiva, see Borgmeier (1940) and Lent (1980).

[12] Chagas, 1908, in Reis, 1909, pp. 1/6. Many of the scientist's papers used in the present article are available from the Biblioteca Virtual Carlos Chagas (www4.prossiga.br/Chagas/). Hereinafter, I will use the page numbering adopted therein.

[13] After joining the Liverpool School of Tropical Medicine in 1899, Ross took part in expeditions to study and combat malaria in Sierra Leone (1899 and 1901) and in Lagos (1901). He published *Instructions for the Prevention of Malarial Fever* (1899), *Mosquito Brigades* and *How to Organise Them* (1902), and *The Prevention of Malaria* (1910); available at sca.lib.liv. ac.uk/collections/colldescs/lstm/ross.htm, accessed on Nov. 7, 2005.

[14] For more on this, see Lobo (1936) and http://www.geocities.com/ferrovias_brasil/itatinga.htm.

[15] The campaign lasted three months. Chagas would later say that he didn't know if his proposed measures had been enforced once he left Itatinga (1908).

[16] The campaign in Xerém will be the subject of a more detailed study, currently in progress.

[17] Ministério da Viação e Obras Públicas (1907): ofício no. 729, May 17, 1907.

[18] Estrada de Ferro Central do Brasil, 6a Divisão Provisória. Construção No. 72 Sete Lagoas, June 17, 1907.

[19] Decree no. 156, of 1890, made it mandatory to draw up a general transportation route plan that would include all Brazilian roads to be explored by concessions. It was only in April 1931 that a commission of technical specialists was appointed to actually draw up such a plan, instituted in the Vargas era under Decree 24.497, of June 29, 1934. In the 1940s, the emphasis shifted from rail to road. The history of the Noroeste do Brasil railroad can be found in Neves, 1958; Castro, 1993; and Queiroz, 1997, 2004.

[20] *Guarantã* is a tree (*Esenbeckia leiocarpa*) of the Rutaceae family. The word comes from the Tupi term *iara-tã*, which means "hard wood." Its extremely resistant timber was used by the Caingangues to make their deadly, cylindrical-shaped weapon called a *borduna*.

[21] One product of this trip and of his subsequent stay in the service of the Noroeste railroad was the paper published in 1911, in collaboration with Adolpho Lutz, in which 23 species of Culicidae were described, including two new ones: *Anopheles matogrossensis* and *Culex scutipunctatus*. In Mato Grosso and the zones near the Paraná and Tietê rivers, they observed the very common presence of *Cellia argytarsis, C. brasiliensis, C. tarsimaculata, C. albimana*, and *Manguinhosia lutzi*.

[22] The branch from Campo Grande to Ponta Porã, on the border with Paraguay and the Bolivian city of Santa Cruz de la Sierra, began operating in the 1950s (Queiroz, 2004).

[23] This is one of the versions of Neiva's image of São Paulo as a locomotive pulling the rest of the country behind it; the first time he used it was when he left his post as head of the Serviço Sanitário de São Paulo (*O Estado de S. Paulo*, May 10, 1920). See Borgmeir (1940, pp. 74, 76).

[24] Our main source here is Manoel Rodrigues Ferreira's still unrivaled book *A Ferrovia do Diabo*, whose first edition came out in 1959.

[25] Author of the *Relatório sobre o estado médico e sanitário na E. F. Madeira-Mamoré* (Report on the medical and sanitary status of the Madeira-Mamoré Railway, Rio de Janeiro, 1913), Belt is cited by Ferreira (205, p. 229). In April 1908, he left for the US because his wife had taken ill.

[26] While journeying through part of the Amazon basin in 1912, Chagas (1913, p. 450) would conclude that there "the pathology of the tropics appears with its true traits, not rarely modified under the more temperate climatic conditions of intertropical zones" (Cruz, 1913, pp. 666, 702-7). This was especially a reference to malaria, which Oswaldo Cruz, in introducing Chagas's report, had called "the hobgoblin of the Amazon" (1913, p. 666).

[27] Before reaching Porto Velho, they conversed in Belém do Pará with representatives of the Port of Pará company, also owned by Farquhar, who was responsible for its modernization. The state government and Oswaldo Cruz agreed upon the yellow-fever campaign he would conduct months later, in Belém, with the help of the physicians and mosquito brigades that had combated the disease in Rio de Janeiro.

[28] Carl Lovelace, author of *Trabalhos da seção médica da Madeira-Mamoré Railway* (Rio de Janeiro, 1913), is cited in Ferreira (2005, p. 233).

[29] After Farquhar went bankrupt during World War I, the Madeira-Mamoré Railway was run by the British until 1972. Ownership of its material assets then passed to the federal government and it has been completely abandoned ever since. Some organizations are fighting to recover the line, considering its tourist potential and the role that its construction played in the history of Brazil.

[30] Ministry of Agriculture, Industry, and Commerce. Report of 1910-11, p. 166. Cited in Thielen (1991, p. 116).

[31] On the sanitation movement and political reforms in public health within this context, see Hochman, 1998; Lima and Britto, 1996; Lima and Hochman, 1996.

[32] Approved in Dec. 1917, by law no. 1596.

[33] With the end of WWI, the International Health Board began efforts to eradicate yellow fever, based on the idea that it would disappear if some of its key foci could be wiped out. The campaign especially targeted *Aedes aegypti* larvae, since this was still considered the only vector of the disease (Löwy, 1998-99, p. 653). See also Benchimol (2001).

[34] Rockefeller Archive Center: RF, RG 5, IHB, series 1-2, box 189, folder 2434.

[35] Letter by IHB director F. F. Russell to George K. Strode, on Jan. 24, 1924. RF, Record Group 5, IHB, series 1, subseries, 2, box 189, folder 2434. RAC.

[36] Paris green was the popular name for copper arsenate, a yellowish-green powder originally used as a pigment by painters and in making fireworks. It is also known as Schweinfurt green because it was first synthesized in Germany by Schweinfurt, in 1814. Highly venomous, it was used as a rat poison in the sewers of Paris—ergo the name Paris green. It was also widely used to paint the hulls of ships, since it prevented the proliferation of barnacles. It was first employed as an agricultural insecticide and then, in the 1920s, mixed with diesel oil, it became an important tool in the control of malaria in Brazil and other countries.

[37] This does not mean that such initiatives were the only component of Oswaldo Cruz's campaigns, as Stevens and other authors seem to suggest.

[38] Letter from George Strode to F. F. Russell, dated June 4, 1924. RF, Record Group 5, IHB, series 1, subseries, 2, box 189, folder 2435. RAC.

[39] Two other Brazilians were present at the Congress: M. de Sousa, who presented a communication on the fight against malaria and its results in Brazil, and Samuel Libânio, who spoke about purging housing in order to combat paludism in Minas Gerais (1926).

[40] Godoy held mosquitoes captive and noted that they did not lay eggs for some days, even if the eggs were mature; they did so, however, as soon as water was placed within reach. This proved that the biological demand to procreate could be delayed, even after complete maturation of the eggs (Godoy and Pinto, 1923, p. 168). Godoy also proved that among mosquitoes settled inside housing, the time between mating and their first blood meal, on the one hand, and the laying of eggs, on the other, could reach twenty days, more than enough time for the hematozoan to complete its life cycle.

[41] They were also adopted in the Baixada Fluminense, but preventive and curative use of quinine was the prime method and would become the mainstay of subsequent campaigns.

[42] Neiva (1941, p. 161); this sentence is found in a 1925 article: "Da malaria e os serviços da Light and Power na Serra do Cubatão."

[43] Busvine (1993) and Packard (2007) are fine references on the worldwide campaign to eradicate malaria, proposed at WHO's 8th World Assembly in 1955, largely deactivated by the 22nd Assembly in 1968, and definitively buried at the Ministerial Conference on Malaria in Amsterdam in 1992.

[44] The latest international literature on the history of malaria has underlined the disease's distinct configurations and the complex nature of its political, social, economic, and environmental dimensions, factors that together have contributed to the disease's continued presence as one of the main afflictions of poor countries. See, for example, the work of Humphreys (2001), Snowden (2006), Packard (2007), and Cueto (2007).

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