

Publication status: This preprint has not been published elsewhere.

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<https://doi.org/10.1590/SciELOPreprints.18322>

Submitted on: 2026-10-07

Posted on: 2026-10-07 (version 1)

(YYYY-MM-DD)

Canids in American Visceral Leishmaniasis: A Historical Review of the Brazilian Case

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Abstract

This article analyzes studies and controversies regarding the role of canids—domestic dogs and wild foxes—in the transmission and control of American visceral leishmaniasis, from a Brazilian perspective, since the identification of the first cases in the early 20th century. The political and institutional factors that shaped these studies and controversies are examined, as well as the measures adopted against hosts and vectors across successive periods characterized by different health policies and health system configurations. The article highlights two forms of resistance to the mass culling of domestic dogs, a cornerstone of public health campaigns against visceral leishmaniasis in Brazil: the opposition stemming from the human populations most affected by it, followed by the growing opposition from scientists and public health experts to this course of action, driven by the fact that it failed to prevent the disease's geographical expansion and urbanization in the country. The article concludes by examining an innovation that helped break the deadlock in visceral leishmaniasis control: the use of insecticide-impregnated collars on dogs, adapting a technique previously applied solely to vector control to animal health. Finally, these sociotechnical processes are contextualized within the broader political and cultural framework of an emerging global health paradigm: One Health. Key-words: canids; American visceral leishmaniasis; public health campaigns in Brazil; zoonosis control; deltamethrin impregnated dog collars; One Health; Animal history.

Introduction

The word *leishmaniasis* refers to a pathological complex "constructed" at the turn of the 19th to the 20th century. Skin ulcers with dozens of names in various parts of the world were linked in 1898 to a protozoan. On the other hand, in 1903, *kala-azar*—a highly lethal disease that affected internal organs and spread epidemically in India—was attributed to another protozoan. A new genus was then proposed to accommodate this organism: *Leishmania donovani*. And in 1906, the protozoan causing the cutaneous disease was reclassified as *L. tropica*. In 1909, physicians working in the state of São Paulo reported the discovery of *Leishmania* in the ulcers of laborers working on the construction of a railroad designed to connect Brazil to Bolivia. This leishmaniasis also affected the mucous membranes and was not prevalent in cities, as in the Old World, but rather in forested areas. Similar diseases with different names across other regions of the

American continent would soon be reclassified as cutaneous or mucocutaneous leishmaniasis.¹

The endorsement of *L. braziliensis* described by Gaspar Vianna (1911, p. 411) and the archaeological evidence supporting the autochthony of the leishmaniasis caused by this parasite are key aspects of the growing acceptance of the concept of American Tegumentary Leishmaniasis (ATL), which was consolidated with the 1948 publication of a book under this title by Samuel Pessôa and Mauro Pereira Barretto, parasitologists from the University of São Paulo.

Regarding visceral leishmaniasis, the uniqueness of the Americas seemed to lie in the virtual absence of this form of the disease, which had already been differentiated in the Old World: Asia and East Africa's *kala-azar*, caused by *L. donovani*; and the visceral leishmaniasis rampant around the Mediterranean, primarily affecting children and dogs, attributed in 1908 to *L. infantum*.

At the turn of the 1920s to the 1930s, a major shift occurred in the understanding of yellow fever. It was recognized primarily as a sylvatic disease caused by a virus, with multiple vertebrate hosts besides humans and several other vectors besides *Aedes aegypti*. Specialists involved in the campaign against the disease in Brazil needed to determine its true extent, and viscerotomies served as one of the primary tools for this purpose. Consequently, starting in 1934, dozens of posthumous cases of visceral leishmaniasis were identified in tissue samples that tested negative for yellow fever.

Carlos Chagas, director of the Oswaldo Cruz Institute, tasked his son, Evandro Chagas, with investigating the new public health problem. In 1936, he traveled to Northeastern Brazil, but the commission led by him soon moved its research to Pará, in northern Brazil. Evandro and his collaborators concluded that the disease occurred exclusively in forested areas with dry terrain and a high concentration of wild mammals—the so-called "*terra firme*." There, seven dogs and one cat were found naturally infected.² In a wild rodent (*saiúá* or *Phyllomys* sp.), granulations suggested *Leishmania*, but it was not possible to go beyond suspicion.

¹ Benchimol and Jogas Junior (2020) reference and analyze the works published at the time on this regard.

² In the floodplain (*várzea*), Chagas and collaborators examined 2,947 people, 397 dogs, and 164 cats, all with negative results for *Leishmania* (Chagas et al., 1937, pp. 321–389; 1938, pp. 138–206; 1938, pp. 89–229).

The vectors appeared to be *Phlebotomus longipalpis* and *Phl. intermedius* (*Lutzomyia longipalpis* and *Lu. intermedia*).³ For Evandro Chagas and his collaborators, the dog could not play the same role it had in Mediterranean visceral leishmaniasis because American visceral leishmaniasis (AVL) was much more dispersed and sporadic. They considered it autochthonous and essentially wild, and incriminated a new species as its causative agent, *L. chagasi* (Cunha & Chagas, 1937, pp. 148–152).

Following the tragic death of Evandro Chagas in 1940, studies on AVL in Brazil slowed down.

The first epidemic identified in the Americas

In the late 1940s, a visceral disease began to appear with unusual frequency in an inland city in the state of Ceará, Northeastern Brazil. Situated in the *caatinga*—a biome characterized by a semi-arid climate—Sobral was a magnet for peasants displaced by frequent droughts. The second government of Getúlio Vargas (1951 to 1954) coincided with another of these socio-environmental events. Impoverished men, women, and children moved from one location to another seeking aid and means of survival. Their ability to resist disease plummeted, and their living conditions exposed them to infections and health hazards of all kinds.

In 1949, Dr. Thomaz Corrêa Aragão began treating children in Sobral with severely enlarged spleens and livers, weight loss, diarrhea, swollen lymph nodes, and anemia. They had previously been receiving treatment for helminthiasis or malaria. Through deduction and by consulting medical literature, Aragão arrived at the diagnosis of *kala-azar*—an Indian word that entered the Brazilian lexicon during those years as *calazar*.

The live cases reported in the medical literature were few. In four decades, since the first patient infected in Brazil was diagnosed in Paraguay (Migone, 1913, pp. 210–218), 34 live cases of visceral leishmaniasis had been recognized, mostly in the states of Pará, Bahia, and Ceará (67.64%). Pathologists from the Yellow Fever Service identified 314 post-mortem cases between 1934 and 1950, nearly half of them in Ceará (149). In the American continent, up until 1954, only 35 cases had been described elsewhere. These data come from Leônidas Deane (1956, pp. 1–162; 1958, pp. 431–449) and Joaquim

³ Ferreira et al., 1938, pp. 1078–1079; Chagas [Agnes], 1939, pp. 1–2; 1940, pp. 327–333. Both species had been described by Lutz and Neiva (1912, pp. 84–95).

Eduardo de Alencar (1959, p. 22)—whom we will discuss shortly—who relied on the publications available to them, as there were no official records in any American country.

The epidemic that erupted in Northeastern Brazil in 1953 drastically altered this picture (Benchimol & Jogas Junior, 2020, pp. 423–537). From that year to 1957, the total number of *in vivo* cases of visceral leishmaniasis on the continent surged to 2,179, with over 90% occurring in that Brazilian region.

In 1953, a Campaign against Visceral Leishmaniasis was established there under the leadership of Alencar, one of the founders of the School of Medicine of Ceará. Samuel Pessôa, a renowned parasitologist from the University of São Paulo, sent two of his assistants to Ceará: Leônidas Deane and his wife, Maria Deane, both former members of Evandro Chagas' team. In meticulous studies, they verified that *Lu. longipalpis* was the main vector of *kala-azar* in the region (Deane & Deane, 1955, pp. 95–118; 1957, pp. 225–246; Deane, 1956, pp. 1–162). They also identified the hoary fox (*Lycalopex vetulus*) as a host animal for *Leishmania*, corroborating the wild reservoir that Evandro Chagas had so earnestly sought.⁴

However, Leônidas and Maria Deane described a disease that occurred in rural areas with a "focal" rather than a scattered pattern, with transmission also occurring to humans and dogs in small inland towns. The pronounced pathogenic effect of the protozoan on foxes—which could become as severely ill as dogs—did not align with an ancient host-parasite relationship. Thus, *kala-azar* must have been imported from the Old World during the colonial period via infected dogs or individuals, "having secondarily affected a highly susceptible wild canid that frequently approaches human dwellings, such as the fox" (Deane, 1958, pp. 431–449 [436]).

Investigations in Ceará showed that *kala-azar* had gone unnoticed for a long time. The small number of diagnoses made up to that point resulted from a lack of adequate care for the rural population and a lack of information among local physicians. Case distribution showed a clear concentration in areas known locally as *boqueirões* and *pés-de-serra*—narrow valleys located between or at the foot of mountain ranges.⁵ Although

⁴ Deane & Deane (1954, pp. 419–421) identified the infection in the very first mammal they examined: a fox that João Moojen de Oliveira, a zoologist at the National Museum in Rio de Janeiro, classified as *Lycalopex vetulus*. During their stay in Northeastern Brazil, they examined 33 foxes and found infection in four (12.1%) of the same species (Deane & Deane, 1955, pp. 61–76; Deane, 1956, pp. 1–162). In 1960, Alencar's team (1961, pp. 175–180) also found natural infection in seven out of 173 foxes (4.4%) captured in Ceará.

⁵ The importance of the *pés-de-serra* (mountain bases) and *boqueirões* (narrow mountain passes) in the epidemiology of visceral leishmaniasis was confirmed by other researchers in the states of

these areas were inhabited by only about 10% of the rural population, they accounted for 63.5% of the cases. From the drier *sertão* (backlands), where approximately 50% of the inhabitants lived, came only 21.7% of cases; and from the mountains, home to 40% of the population, just 14.7% (Deane & Deane, 1954, pp. 703–707; 1955, pp. 75–87). The most affected group was children aged 0 to 9 years. *Kala-azar* was endemic, with epidemic periods linked to droughts and cyclic increases in the number of susceptible individuals, particularly among children.

Alencar and collaborators (1956, pp. 33–47) investigated the disease in the Jaguaribe River valley, along whose banks carnauba palms abounded. Once the powder used in wax manufacturing was removed, the straw remained fermenting in the backyards of houses during the rainy winters, creating a favorable environment for the reproduction of phlebotomine sandflies, the transmitters of the disease.

As in other parts of the world, the Campaign against Visceral Leishmaniasis in Ceará involved the application of DDT (dichloro-diphenyl-trichloroethane) in homes and domestic animal shelters; the discovery and treatment of human cases with available antimonials;⁶ and the identification and elimination of thousands of dogs with confirmed or suspected infection.

The Fox and the Debates on the Indigenous Origin of AVL

Surveys conducted from then on showed that the exodus of rural workers from the Northeast was increasing the incidence of visceral leishmaniasis in other regions of Brazil. The institutional network capable of hosting studies on rural endemic diseases now included three research centers affiliated with the National Department of Rural Endemic Diseases (DNERu), an agency of the Ministry of Health created in 1956: the Bahia Research Nucleus, now the Gonçalo Moniz Institute; the Belo Horizonte Research Center, which would later be named René Rachou; and the Aggeu Magalhães Research Center, in Recife (Santos, 2025). The work carried out at these institutions primarily targeted Chagas disease, malaria, and schistosomiasis, but visceral leishmaniasis gained

Piauí, Bahia, and Minas Gerais (Deane, 1956, pp. 1–162; Martins, Brener, Mourão, Lima, Souza & Silva, 1956, pp. 557–563). The disease also raged along the banks of rivers such as the Jaguaribe (Ceará) and the Piancó (Paraíba) (Alencar, Holanda, & Cavalcante, 1956, pp. 33–47; Alencar, 1962, pp. 367–369), or along the coast, as shown by viscerotomies, but it was rare or absent in areas at altitudes higher than 800 meters.

⁶ The main drugs used were Solustibosan (sodium antimony gluconate), manufactured by Bayer, and Glucantime (N-methylglucamine antimonate), by Rhône-Poulenc, which arrived in Brazil in 1948 (Benchimol, Barbeitas, & Jogas Junior, 2026).

growing importance, as attested by the first Conference on Kala-Azar, held in Salvador, Bahia, in 1960. During this event, the creation of the Brazilian Society of Tropical Medicine was proposed—a relevant episode in the resurgence of medicine dealing with pathologies that, in the following decade, would be reclassified as "neglected diseases," and later as diseases of poverty (Benchimol & Jogas Junior, 2020, pp. 614–616).

During this same period, important studies on American Tegumentary Leishmaniasis (ATL) were carried out by Oswaldo Paulo Forattini, from the School of Hygiene and Public Health at the University of São Paulo; and by four teams from Central and North America: Marshall Hertig, Alexander Graham Bell Fairchild, and collaborators at the Gorgas Memorial Laboratory in Panama, on the wild hosts and vectors of this leishmaniasis; Francisco Biagi Filizola's team at the Universidad Nacional Autónoma de México, which implicated *L. mexicana* as the causal agent of *úlceras de los chicleros*, one of the forms of ATL; Hervé Alexandre Floch's team at the Institut Pasteur de la Guyane Française, which implicated *L. tropica guyanensis* as the cause of *pian-bois*; and the team from the London School of Hygiene & Tropical Medicine, which established the Dermal Leishmaniasis Research Unit in British Honduras (Benchimol & Peixoto, 2022). After conducting research in this British colony, Percy Cyril Claude Garnham, a prominent figure in European parasitology, sent one of his disciples there, Ralph Lainson. In the early 1960s, Lainson and John Strangways-Dixon, an entomologist from a university in Jamaica, published foundational studies on the wild reservoirs of *L. mexicana*, shattering the assumption that *L. braziliensis* was the sole causal agent of all forms of ATL (Lainson & Strangways-Dixon, 1962, pp. 1596–1598; 1963, pp. 242–265; 1964, pp. 136–153).

Around that time, the host-parasite relationship was framed in a less anthropocentric way than that used at the beginning of the 20th century. There was a growing interest in zoonoses and the evolutionary dynamics of the host-parasite relationship, which were heavily affected by the intensification of human interventions in the environment.

In 1965, at the Evandro Chagas Institute (IEC) in Belém, capital of the state of Pará, Lainson and another disciple of Garnham, Jeffrey Jon Shaw, founded the first Wellcome Parasitology Unit with the primary goal of investigating the populations of

wild animals and insects hosting *Leishmania* in the Amazon. They began their work shortly after the civil-military coup of March 1964.⁷

In the following years, major agricultural, mining, and infrastructure projects would devastate the environment and the indigenous populations of the so-called Legal Amazon,⁸ bringing huge profits to consortiums of politicians, military officers, and private companies, as well as stimulating research opportunities regarding protozoa and other pathogens that thrived in the altered environments. Leishmaniasis cases grew explosively. Belém and Manaus, the capital of the state of Amazonas, became important hubs for knowledge production on this and other diseases in Northern Brazil and neighboring countries.

Lainson and Shaw's investigations led them to rediscover visceral leishmaniasis and revalidate the ideas of the patron of the institution where they worked. They were "particularly excited," as Lainson (1988, pp. 27–32 [29]) notes, upon isolating "*L. chagasi* from the viscera of two apparently healthy foxes (*Cerdocyon thous*), killed in a sparsely populated area on the outskirts of Belém in 1968." This observation ran counter to the prevailing opinion among specialists, who considered *L. infantum* or even *L. donovani* to be the etiologic agent of AVL. For Lainson and Shaw (1978, pp. 595–600), this paradigm represented an obstacle to appreciating the true epidemiological situation in the Americas that was just as paralyzing as the belief that all forms of ATL were due to *L. braziliensis*.

Foxes were seen with increasing frequency on the outskirts of Belém searching for food, especially in chicken coops adjacent to human dwellings, as a result of the drastic alterations taking place in the local ecosystem. They belonged to a different species than the ones captured in Northeastern Brazil. In 1968, five foxes were killed in a cultivated field of the Northern Agricultural Experimental Research Institute (Ipean),

⁷ Jeffrey Shaw (2016, pp. 23–42 [25]) wrote: "(...) during our early years we worked in an academic vacuum in terms of Brazilian parasitology." And in the interview he granted us, he reiterated: "There were no more Brazilians left, everyone had left Brazil due to political problems. (...) The dictatorship stripped everyone of their rights. (...) The best ones left" (Shaw, April 18, 2018). The setup of the Wellcome Parasitology Unit at the Evandro Chagas Institute and the work carried out there by Lainson and Shaw's team are analyzed in Shaw (2016, pp. 23–41) and Benchimol & Peixoto (2022).

⁸ The Legal Amazon, established in 1953 for regional economic development, encompassed the states of Maranhão, Goiás, and Mato Grosso. The configuration defined by the 1988 Constitution included Tocantins, Roraima, and Amapá. The current coverage area of the Legal Amazon corresponds to the entirety of the states of Acre, Amapá, Amazonas, Mato Grosso, Pará, Rondônia, Roraima, and Tocantins, along with part of Maranhão, totaling an area of about 61% of the Brazilian territory. Its population, however, corresponds to 12.32% of Brazil's total inhabitants.

and a sixth in the Utinga forest, an area where parasitologists and virologists from the Evandro Chagas Institute conducted research.⁹ Zéa Constante Lins, a bacteriologist who was by then married to Ralph Lainson, inoculated hamsters with a kidney suspension from four of the animals. One month later, one of the hamsters died with a high parasite load of *Leishmania* (Lainson, Shaw & Lins, 1969, pp. 741–745).

The authors cautiously referred to *L. donovani*. Their primary bibliographical references were still Leônidas Deane's professorial thesis (1956) and the article he had published with Maria Deane (1962, pp. 198–212). According to these scientists, *Leishmania* parasites were as scarce in the blood of foxes and dogs as they were in humans, but dermal parasitism in canids could be intense, making them an important source of sandfly infection. Furthermore, the disease progressed in the same manner in both animals. Leônidas and Maria Deane considered it likely that epizootics occurred among foxes just as they did among dogs. They concluded: "the severity of the disease in the fox suggests that it does not represent the ancient indigenous reservoir that Chagas was seeking, but rather that it is a more recent host of *L. donovani*" (Deane & Deane, 1962, pp. 198–212 [209]).

In the work published almost ten years later on the infected yet asymptomatic *C. thous* fox, Lainson, Shaw, and Lins (1969, pp. 741–745) considered that it could be the "ancient indigenous reservoir" (p. 744) sought by Evandro Chagas.¹⁰

Several researchers had been searching for wild reservoirs of visceral leishmaniasis in Brazil. They had examined, without success, more than a thousand animals, including foxes and other carnivores, primates, marsupials, rodents, and Chiroptera (bats).¹¹ Organisms that appeared to be Leishman-Donovan bodies were found by Leônidas Deane in the viscera of a two-toed sloth (*Choloepus didactylus*) in the

⁹ On the virology research conducted at the laboratory established by the Rockefeller Foundation at the Evandro Chagas Institute, including studies on sandfly-borne viruses, see Cláudia Santos (2025) and Benchimol & Peixoto (2022).

¹⁰ Soon another *C. thous* with infection was found, also healthy (Lainson & Shaw, 1971, pp. 21–57).

¹¹ Deane and Deane (1962, pp. 198–212 [205]) cited Chagas et al. (1938, pp. 89–229); Pondé et al. (1942, pp. 333–352); Deane & Deane (1955, pp. 61–76); and Deane (1958, pp. 431–449). In his professorial thesis, Deane (1956, pp. 1–120 [77]) provides a detailed review of the works published up to that point regarding reservoirs. Benchimol & Jogas Junior (2020) mention other unsuccessful works.

Amazon, but he ultimately concluded that they were a stage in the life cycle of *Endotrypanum schaudinni*.¹²

In Tajikistan, Central Asia, three Russian researchers determined that the jackal (*Canis aureus*) was a reservoir of *L. donovani* (Latyshev, Kryukova, & Povalishina, 1951, pp. 35–62).¹³ Sometime later, *Leishmania* parasites were isolated from squirrels and gerbils in an area endemic for visceral leishmaniasis in Kenya (Heisch, 1957, p. 183; Heisch, Grainger, & Harvey, 1959, pp. 158–159). For Lainson, Shaw, and Lins (1969, pp. 741–745), the opossum was likely a reservoir, as it maintained an even closer relationship with humans than foxes did. And indeed, in the 1980s, *Didelphis albiventris* was found in Jacobina, in the state of Bahia, naturally infected with the etiologic agent of AVL (Sherlock et al., 1984, p. 511; 1988, p. 141; 1988, pp. 23–27).

Lainson and Shaw's team succeeded, under laboratory conditions, in transmitting the *Leishmania* obtained from the infected fox to a hamster via the bite of *Lu. longipalpis*, but they did not find this sandfly species in Pará, not even in Abaetetuba, where Evandro Chagas' team had conducted research thirty years earlier (Lainson, 1988, pp. 27–32). In fact, human cases of visceral leishmaniasis were still rare in Northern Brazil.

In 1962, Alencar, Pessoa, and Costa (1962, pp. 371–377) visited Santarém, a port city in Pará located at the confluence of the Tapajós and Amazon rivers. They examined 500 people and confirmed visceral leishmaniasis in two Northeastern children and one native to Pará. Of 617 dogs examined, 19 (3.1%) had positive parasitological tests for *Leishmania*; and of the 101 sandflies captured in Santarém and Belém, both inside and outside houses, 62 were dissected and 22 were infected with *Leishmania*. Of these 62, 33 were *Lu. longipalpis*, but they were found exclusively on tree trunks and in armadillo burrows.

Shortly before Lainson and Shaw settled in Belém, Orlando Rodrigues da Costa, professor of parasitology at the Faculty of Medicine of the University of Pará and director of the Evandro Chagas Institute, traveled to Marajó Island at the mouth of the Amazon River, where he encountered "a true medical rarity among us": the 12th case of *kala-azar*

¹² Deane (1956, pp. 1–120 [79]). These parasites were studied by Shaw (1964), who, in Central America, also found sloths infected with *Leishmania*. Other works on *Endotrypanum* would later be published by Shaw (1969, pp. 1–132; 1992, pp. 107–116). Studies by Lainson, Shaw, and collaborators on the importance of sloths as hosts for *Leishmania* associated with ATL are cited in Benchimol & Peixoto (2022).

¹³ British parasitologist Cecil Arthur Hoare (1954, pp. 37–40) published a review in English on this and other Russian-language articles concerning the leishmaniasis.

in a living individual in Pará.¹⁴ Costa identified neither infected dogs nor sandflies inside or outside the dwellings. He then concluded that the patient found confirmed that visceral leishmaniasis in Pará was “sporadic, exclusively rural or sylvan, affecting indifferently man or the dog that lives in contact with the jungle. Possibly the primary reservoir is a wild animal not yet identified in the region” (Costa, 1966, pp. 91–98 [97]).

A decade passed before Lainson and collaborators (1981, pp. 251–253; Silveira et al., 1982, pp. 830–832) encountered another fatal case of human visceral leishmaniasis originating from Campinas in Marajó Island. In January 1982, they examined a three-year-old boy presenting clinical signs in another locality on the island, Camará (Lainson et al., 1983, pp. 323–330). Two dogs in this village were infected, and antibodies against the parasite were detected in 20% of 80 others examined using the indirect immunofluorescence assay (IFA) (Lainson et al., 1984, pp. 1–8).¹⁵ Only then, after 46 years of an almost total absence of information regarding *Lu. longipalpis* in Pará, was the vector insect observed in Marajó, when Lainson and collaborators conducted epidemiological surveys related to those two human cases. They found the sandfly inside houses, though in small numbers because DDT had been applied by the anti-malaria service, but there were large concentrations of *Lu. longipalpis* in the chicken coops adjacent to these dwellings (Lainson et al., 1986, pp. 83–124).¹⁶

Marajó Island is close to Belém, “and so began 23 years of epidemiological research on visceral leishmaniasis in the Municipalities of Cachoeira do Arari and Salvaterra” (Shaw, 2016, pp. 23–42 [32]). The primary focus was not human disease per se, but rather the synergies between the parasite and its hosts. Among the 2,637 animals they examined, of various species, *L. chagasi* was isolated exclusively from the fox *C. thous* (Silveira et al., 1982, pp. 830–832). Furthermore, among 23 specimens captured in sparsely populated agricultural areas near forests on the outskirts of Belém—where there

¹⁴ Between 1936 and 1940, Evandro Chagas’s team found eight living cases in the municipalities of Abaetetuba (5) and Moju (3), in *terra firme* areas with primary or secondary forests (*capoeiras*) (Chagas, 1938, pp. 1323–1353). Of the 41 post-mortem cases identified by viscerotomy in 1934, three were in Pará. Of the 327 cases of kala-azar diagnosed in the same manner in Brazil from 1934 up to November 1955, 18 belonged to Pará (Deane & Deane, 1962, pp. 198–212 [199]).

¹⁵ The literature recorded 35 autochthonous human cases of visceral leishmaniasis in Pará, twelve of which were on Marajó Island. Chagas et al. (1938, pp. 89–229); Deane [Leônidas] (1938, pp. 315–321); Deane [Maria] (1947, pp. 7–14); Alencar, Pessoa, & Costa (1962, pp. 371–377); Costa (1966, pp. 91–98); Lainson, Miles, & Shaw (1981, pp. 251–253); Lainson et al. (1983, pp. 323–330).

¹⁶ Promastigotes were found in eight (0.5%) out of 1,500 dissected specimens (Ryan et al., 1984, pp. 547–548). The parasite proved to be indistinguishable from *L. chagasi* isolated from man and the fox at the same location (Lainson et al., 1985, pp. 223–226).

was no prior record of canine or human visceral leishmaniasis—three were infected with *Leishmania* (13%). Likewise, another 10 foxes out of 25 (40%) captured on Marajó Island, in a rural area with sporadic human and canine visceral leishmaniasis, were infected (Lainson, 1983, pp. 569–596). The parasite proved to be identical to the one found in dogs and humans in the same area and in other regions of Brazil (Silveira et al., 1982, pp. 830–832; Braga et al., 1986, pp. 143–145).

For Lainson and his collaborators, the fact that the infections in the wild canid were inapparent suggested an ancient and well-established host-parasite relationship. They then adopted, without further hesitation, *L. chagasi* as the agent of American Visceral Leishmaniasis (Lainson, Shaw, Silveira, & Fraiha, 1983, pp. 323–330 [324]). The ideas that had led Evandro Chagas and Aristides Marques da Cunha (1937, pp. 148–152) to propose this protozoan species as the etiologic agent of an autochthonous disease were revisited by Lainson (1983, pp. 569–596) in a communication to the Royal Society of Tropical Medicine and Hygiene.

Drawing on the work of Saul Adler (1940, pp. 173–175; 1964, pp. 35–96) and Adler and Oskar Theodor (1957, pp. 203–226) from the Hebrew University of Jerusalem, Lainson and Shaw (1972, pp. 44–48) defended the validity of *L. chagasi* primarily on the basis of epidemiological deductions. Benchimol & Jogas Junior (2020) analyzed the long-standing conflict between unicists and pluralists dating back to the earliest studies on leishmaniasis. In 1908, when Charles Nicolle differentiated *L. infantum* from *L. donovani*, his theory faced criticism from unicists. If *L. infantum* is accepted as a valid species, wrote Lainson and Shaw (1972, pp. 44–48 [44]),

The taxonomy of the parasite causing New World visceral leishmaniasis must be reconsidered. (...) Like Adler & Theodor (...) we regard American visceral leishmaniasis as an indigenous disease, stemming from a wild source. On grounds of geographical isolation alone, there would seem to be even more reason for separating off the parasite of American visceral leishmaniasis than there is for the distinction between *L. donovani* and *L. infantum*.

Marcel Hommel (1978, pp. 5–102), of the Liverpool School of Tropical Medicine, reiterated the primacy of *L. donovani* and proposed subspecific designations—*L. d. donovani*, *L. d. infantum*, and *L. d. chagasi*.

Before the wild vertebrate host became the primary foundation for *L. chagasi* as an autochthonous species, those who defended its status relied above all on the specificity of the insect vector. If the etiologic agent of AVL had indeed been imported by the Iberians and their dogs, it must have come to be transmitted by a sandfly species entirely different from those naturally associated with the cycles of *L. infantum* and *L. donovani* in the Old

World. According to Adler and Theodor (1957, pp. 203–226 [217]), in that part of the globe, the vectors of visceral leishmaniasis in humans and dogs were restricted to sandflies of the *major* group. It was improbable that *L. infantum* could have undergone such an abrupt adaptation to a vector of a completely different genus. "The most striking aspect of Deane & Deane's findings is the relatively high rate of infection in *P. longipalpis* fed on human cases. This infection rate is higher than any hitherto observed in the Mediterranean region"—wrote Adler and Theodor (*ibid.*, p. 215).¹⁷

Lainson and Shaw endorsed this viewpoint and raised several additional objections to the importation of *L. infantum* into the Americas: there was no plausible explanation for the rapid spread of the disease at a time when communication and transport links between the affected regions in the continent were extremely rudimentary. Furthermore, given that very few Old World sandflies became experimentally infected after feeding on a human with Mediterranean visceral leishmaniasis, it was improbable that the strains causing the disease in South America had derived from individuals who had crossed the Atlantic. The fundamental question was whether the disease had been introduced via dogs. However, canids were well established throughout the Americas long before the arrival of Europeans; thus, there was no reason why they should not have possessed their own *Leishmania* species—wrote Lainson and Shaw (1979, pp. 1–116; see also Lainson, 1982, pp. 137–179).

This theory was challenged by Robert Killick-Kendrick, an old friend of Lainson's at the London School of Tropical Medicine attached to the Department of Zoology and Applied Entomology at Imperial College; A. J. Leaney, from the same institution; David H. Molyneux, a biologist at the University of Salford, also in the United Kingdom; and Jean-Antoine Rioux and Geneviève Lanotte, from the Faculty of Medicine in Montpellier. Killick-Kendrick and his collaborators (1980, pp. 563–565) showed that isolates of *L. d. infantum* from France developed well in the midgut of laboratory-reared *Lu. longipalpis*. Rioux and collaborators had reported the experimental transmission of this protozoan to a dog through a single bite of *Phlebotomus ariasi*, observing a long incubation period of the parasite in the animal. Lanotte and collaborators, in turn, demonstrated that naturally infected dogs survived for many months and would therefore have been capable of enduring the journey to the Americas. But could *Leishmania* from southern Europe be

¹⁷ They were referring to the article by Maria and Leônidas Deane (1955, pp. 347–364) on the infection of *Phl. longipalpis* fed on a naturally infected fox.

transmitted by Neotropical sandflies? Killick-Kendrick, Leaney, and Paul Ready (1975, pp. 1–7; 1977, pp. 429–440) developed methods for establishing and maintaining colonies of *Lu. longipalpis* in the laboratory. Thanks to this, the British and French researchers were able to compare the susceptibility of this sandfly to a strain of *L. d. infantum* from the Cévennes, in south-central France, with that of its natural vector in that region, *Phl. ariasi*, and found no remarkable difference (Killick-Kendrick et al., 1980, p. 563).

Lainson and Shaw (1983, pp. 569–596 [587]) counterargued that "the highly important migration of the parasite to the foregut of experimentally infected sandflies" had not been observed, and thus there was no evidence that *Lu. longipalpis* could actually transmit *L. d. infantum*. It was a strong argument, but that of Killick-Kendrick and collaborators was supported by other points.

Using a recent biochemical technique, Michael L. Chance (1979, pp. 55–74) of the Liverpool School of Tropical Medicine found no differences among four isoenzymes of *Leishmania* isolated in Brazil, Sudan, Ethiopia, Kenya, France, Spain, Tunisia, and India. In Senegal, a region frequented by many colonizers on their journeys to and from the Americas, *Leishmania* from dogs had not yet been differentiated from human visceral leishmaniasis, and thus "the possibility that some populations of *L. chagasi* may have originated from West Africa cannot yet be excluded" (Killick-Kendrick et al., 1980, p. 564).¹⁸

In the paper presented to the Royal Society, while this controversy was boiling, Lainson (1983, pp. 569–596) emphasized the infected, yet asymptomatic, foxes found in Pará. However, prior to that, he had to neutralize the evidence obtained by Leônidas and Maria Deane in Northeastern Brazil. In a study on animals in the epidemiology of South American leishmaniasis, Lainson and Shaw (1979, pp. 1–116 [83]) argued that the number of foxes examined by the two Pará scientists was too small to rule out the possibility of chronic, asymptomatic infections in nature. The signs of severe disease in the specimens examined by them suggested that *L. vetulus* was not a suitable host for the parasite. Lainson and Shaw deemed it more probable that it was an accidental host infected "by the bite of some sandfly species (possibly not *Lu. longipalpis*) which normally maintains a cryptic infection in some other wild animal (a sylvatic species?)." And they introduced a rodent into the equation, based on the observation made by Ítalo

¹⁸ Philip J. Gardener (1997, pp. 1069–1088) endorsed this theory and introduced African slaves into the framework of the export of *kala-azar* from the Old World to the New World.

Sherlock and Saulo Almeida (1970, pp. 175–181) regarding a sharp drop in the incidence of visceral leishmaniasis in Jacobina, Bahia, following a campaign against rodents implicated in a bubonic plague outbreak in the region.

For Lainson, the parasite from *C. thous* was biochemically indistinguishable from that found in humans from various endemic areas of Brazil; and since the foxes examined in Pará showed no signs of disease, the species could be “the long-sought, primitive host. The animal is widely distributed in the Americas, and shows a preference for forested or wooded areas associated with natural or man-made savanna” (Lainson, 1983, pp. 569–596 [588]). In a subsequent communication, Lainson and collaborators (1987, p. 517) further argued:

Canids, including the domestic dog, reached South America in the Pleistocene, some 2–3 million years ago.¹⁹ (...) The rôle of neotropical canids as primitive reservoirs of *L. (L.) chagasi* throughout the geographic range of AVL clearly needs investigation, and information on their ecology and the fox/parasite/vector interface is particularly desirable.

The transmission cycle among foxes was not clear. The authors assumed that it occurred in open country, far from villages, or in the forests adjacent to them, where a transmission cycle involving other mammal species might exist.

However, the examination of approximately 150 wild animals (mainly rodents and marsupials) failed to reveal any evidence that could incriminate, as a reservoir, any animal species other than the fox, *C. thous*. (Lainson et al., 1984, pp. 1–8 [5])²⁰

Lainson made contact with one of the world's leading experts in canid ecology, David Macdonald, from the University of Oxford. The study of fox ecology on Marajó Island began in 1988, with the participation of another British zoologist, Orin Courtenay, who was then starting his PhD at the London School of Hygiene and Tropical Medicine. One of the first papers they produced described the fox's relationship with the peridomestic environment and demonstrated the infectivity for *Lu. longipalpis* of an experimentally infected fox (Lainson et al., 1990, pp. 135–137).

Courtenay, Macdonald, Lainson, Shaw, and Dye (1994, pp. 273–279) conducted a comparative serological study on dogs and foxes, assessing the former through

¹⁹ They cited zoologist Ernest Pillsbury Walker and colleagues (1975), who listed twelve living species, including foxes of the genera *Cerdocyon*, *Urocyon*, and *Dusicyon*; the *Chrysocyon* wolf; the wild dogs *Atelocynus* and *Speothos*; and the domestic dog *Canis*.

²⁰ Also reproduced in Lainson et al. (1986, pp. 83–124 [92–93]). The authors mention there 179 wild animals examined, mainly rodents and marsupials: *Didelphis marsupialis* (64); *Philander opossum* (15); *Metachirus* sp. (5); *Marmosa murina* (3); *Proechimys* sp. (53); *Rattus rattus alexandrinus* (31); *Mesomys* sp. (1); *Procyon lotor* (2); *Dasypus novemcinctus* (4); *Tamandua tetradactyla* (1) (Edentata) (ibid., p. 93).

household surveys and the foxes via capture and radiotelemetry. They found that the incidence of leishmaniasis in dogs was higher during the dry season, with greater prevalence among hunting dogs that frequently roamed sylvatic areas. Among foxes, on the other hand, positive results were obtained for a longer duration due to a lower mortality rate among them.²¹

Apparently, infections among foxes were not associated with visits to human settlements. The transmission cycle became clearer following a cohort study on Marajó Island involving foxes, dogs, and sandflies, now with the participation of Rupert Quinnell, also from the London School of Hygiene & Tropical Medicine (Quinnell et al., 1997, pp. 143–156). The data obtained cast doubt on the validity of dog culling as a control method for visceral leishmaniasis—an issue, as we will see, that was already highly controversial among experts involved in disease control in Brazil.

The studies on Marajó Island showed that *Lu. longipalpis* proliferated in rural dwellings and animal shelters untreated with insecticides. Chickens served as excellent hosts for large colonies of the vector, since it was not routine to spray chicken coops during antimalarial programs. Foxes, the sylvatic reservoirs of the causal agent, frequently approached human habitations to prey on poultry, bringing the infection to the peridomestic population of *Lu. longipalpis*. Once infected, these insects transmitted the parasite to dogs. Developing generally severe disease with high parasite loads in the skin, this animal became the primary source of infection for humans and other dogs.

Courtenay challenged the identification of the foxes studied by Leônidas and Maria Deane in an article published with Paul Johnson, his colleague at Oxford, and two researchers from the Federal University of Ceará. They argued that the presence of *L. vetulus* (*Dusicyon vetulus*) in Northeastern Brazil represented an unprecedented northward extension of the area inhabited by the species. “We therefore ask whether the historical incrimination of *D. vetulus* as a reservoir of *L. chagasi* should not have referred, in fact, to *C. thous*, which is the only other zorro species to occur in this region of Brazil” (Courtenay et al., 1996, pp. 498–502 [498]).

²¹ In another study on the social organization and feeding ecology of *C. thous* in the Brazilian Amazon, Macdonald and Courtenay (1996, pp. 329–355 [330]) observed that “some zorros lived as family groups with close affiliations between parents and adult offspring, and that the habitat (and therefore presumably the resource base) suffered radical seasonal changes through flooding. We also discovered that while we saw the zorros often, the habitat made it impossible to observe them continuously; therefore, we had to use their movement patterns to make inferences about their social behaviour”.

The British zoologist and parasitologist was led to reconsider his critique by Carlos Costa, author or co-author of important works on the role of animal and human hosts in the transmission of visceral leishmaniasis, after the disease erupted epidemically in Teresina, capital of the state of Piauí, in the 1980s.²² Costa had the habit of taking his son to the zoo. On a Sunday, upon arriving at the foxes' cage, they found it empty. The keeper said they were in quarantine because a new, different fox had arrived.

We went over to where they were. There were two cages: one with the two foxes that were already in the zoo—two *Cerdocyon*, larger and more robust—and one slender fox that looked more like a maned wolf, with a fine snout. Orin had worked with foxes in Pará alongside Lainson. He was married to a Brazilian woman. I secured some funding and proposed: ‘Come here to Piauí, there’s a *Lycalopex* for you to see.’ ‘Ah, I don’t believe it,’ he said. [...] I brought Orin, arranged a visit [...] When he put his hand on the animal, he admitted: ‘you’re right, it’s *Lycalopex*.’ I asked: ‘how do you know?’ And he replied: ‘the fur. *Lycalopex* fur is soft like a cat’s; *Cerdocyon* fur is stiff, it pricks your hand.’ Afterwards he performed biometrics and confirmed it. We published the paper [Costa & Courtenay, 2003, pp. 593–594] [...] Because I felt offended when I read their article. It was very irreverent—a colonialist attitude. They wouldn’t have done that to a scientist they considered an equal, but they did it to Professor Deane! (Costa, interview, June 9, 2022)²³

Courtenay, Macdonald, and three collaborators (2005, pp. 45–54) investigated a population of *Pseudalopex vetulus* in Unaí, a municipality in the northwestern part of the state of Minas Gerais. It was the first field study on the social behavior of this species endemic to the Cerrado areas of central Brazil. “Unique among New World canids, the hoary fox is predominantly insectivorous, consuming large quantities of termites” (p. 45). Phylogenetically, it was considered closer to the wolf-like canid lineage that had diverged 7 million years prior from a common North American ancestor than to the vulpine lineage, or “true foxes,” an older branch dating back 10 million years.

Changes in Public Health and the Urbanization of the Leishmaniasis

²² See for instance Silva et al., 2001, p. 487; Soares et al., 2004, p. 210; Costa et al., 2006; and Gomes et al., 2007, pp. 127–133.

²³ A reference work on the subject of *Leishmania* spp. hosts still states that Leônidas and Maria Deane identified as *Lycalopex vetulus* an animal that was actually the “crab-eating fox, *Cerdocyon thous*” (Roque & Jansen, 2014, pp. 233–273 [246]). According to Nascimento (2013, p. 14), the hoary fox (*Pseudalopex vetulus*), historically designated as *Dusicyon (Lycalopex) vetulus* or simply *L. vetulus*, is a wild canid native to Brazil and commonly found in the northeastern semi-arid region living alongside livestock. Lemos and collaborators (2013, pp. 160–171) analyze the rapid population decline of *L. vetulus*—the only Brazilian canid species endemic to the Cerrado—due to severe anthropogenic pressures: deforestation, roadkill, predation by domestic dogs, disease, and retaliatory killing for alleged predation on domestic livestock.

In the early 1970s, Lainson and Shaw (1973, pp. 1–19; 1974, pp. 93–114) grouped the New World *Leishmania* related to ATL into two "complexes": *mexicana* and *braziliensis*.²⁴ It was not a stabilized taxonomy; on the contrary, it revealed many unresolved issues investigated by the teams of Jean-Antoine Rioux at the University of Montpellier; Wallace Peters and collaborators at the Liverpool School of Tropical Medicine; and the London School of Hygiene and Tropical Medicine, where Robert Killick-Kendrick was prominent. The studies conducted by these teams and those with which they interacted in the Americas produced profound changes in the understanding of the region's leishmaniasis by demonstrating that parasite populations—along with their respective vectors and vertebrate hosts—were far more diverse than previously imagined. This added complexity to the protocols for treating patients and for preventing or addressing outbreaks across highly varied ecosystems.

In Brazil, in 1970, control actions became the responsibility of the Superintendency of Public Health Campaigns (Sucam), which incorporated the National Rural Endemic Diseases Department (DNERu) and the malaria and smallpox eradication campaigns. These were the "dark years" (*anos de chumbo*) under the government of General Emílio Garrastazu Médici (1969–1974), the most violent and arbitrary of the civil-military regime, at a time when economic growth was gaining momentum alongside intense income and urban concentration. But when General Ernesto Geisel (1974–1979) assumed the presidency of Brazil, the difficulties faced by its economy were already evident. The collapse of the international monetary system established in 1944, the devaluations of the US dollar, and the "oil shock" resulting from the Yom Kippur War (1973) caused a widespread rise in prices and led to a drop in economic activity, as well as in the investment capacity of industrialized nations. Their economies entered a period of stagnation, and unemployment rates reached levels unprecedented in the post-war era. Through the II National Development Plan (II PND), launched in 1974, the Geisel administration sought to overcome the crisis by means of a "flight forward" (*fuga para frente*), a phrase widely used at the time. The objective was to achieve self-sufficiency in basic supplies, strengthen technological and scientific capacity, and reduce the Brazilian

²⁴ The *Leishmania mexicana* complex included: *L. mexicana mexicana*; *L. mexicana amazonensis* n. sp.; *L. mexicana pifanoi*; and *L. enriettii*. The *Leishmania braziliensis* complex was formed by *L. braziliensis braziliensis*; *L. braziliensis guyanensis*; *L. braziliensis panamensis* nov. s. sp.; and *L. peruviana*.

economy's external dependence. The State and state-owned enterprises played a key role in this development plan.

Research projects, scholarships, and programs sponsored by national and international agencies then multiplied, giving growing dynamism to the network of institutions and researchers dedicated to leishmaniasis and other "neglected diseases." The expression was used for the first time by Kenneth S. Warren, after taking over the leadership of the Health Sciences Division of the Rockefeller Foundation (RF), in 1977. Resources were to be allocated to major international scientific institutions so that they could promote research in collaboration with institutions and scientists from developing countries in order to link "the bench with the bush" (*apud* Keating, 2014, pp. S24–S30 [S25]; see also Warren & Jimenez, 1988). In 1972, the National Council for Scientific and Technological Development (CNPq), Brazil's science funding agency, launched the Integrated Program for Endemic Diseases (PIDE); two years later, the WHO and other agencies created the Special Programme for Research and Training in Tropical Diseases (TDR).²⁵

In Brazil and other countries, veterans began to interact with younger researchers trained in graduate programs in the new techniques of biochemistry, immunology, molecular biology, and other disciplines with a powerful influence on biomedical research—including the taxonomy of *Leishmania* and the epidemiology of leishmaniasis, as shown by Benchimol (2026).

In the introduction to the proceedings of a workshop held at the Aggeu Magalhães Research Center in Recife to discuss the situation of leishmaniasis, Sinval Pinto Brandão-Filho (1993, pp. 1–324 [ix]) wrote: "The increase in incidence, the spectrum of morbidity, and the expansion into new areas are truly surprising, especially the process of urbanization of leishmaniasis, whether visceral or cutaneous."

Another shift in the country's health policies was getting underway. The creation of the Unified Health System (SUS) in 1988 dismantled the two pillars of the programs against leishmaniasis and other diseases: centralization and verticality. The Constitution promulgated on October 5 of that year mandated the transfer of health responsibilities from the Federal Government to states and municipalities—a process that would involve numerous difficulties. The decentralization of medical care proceeded much faster than

²⁵ On policies targeting neglected diseases, see, among others, Molyneux et al. (2021, pp. 169–175), Hotez et al. (2006, pp. 23–33), and Barbeitas (2026, pp. 85–104).

that of endemic disease control and epidemic crises, both of which required the modernization of the epidemiological surveillance system (Benchimol, Barbeitas, & Jogas Junior, 2026).

The National Health Foundation (FNS), established in 1990, replaced Sucam and the Public Health Services Foundation. In 1994, the control of cutaneous leishmaniasis was transferred to the National Coordination of Sanitary Dermatology (CNDS), while actions against visceral leishmaniasis became the responsibility of a municipal body tasked with diseases and conditions transmitted by domestic and synanthropic animals. Sucam personnel were transferred to municipal administration, but the organization and efficacy of the Zoonosis Control Centers (CCZs) across Brazil's thousands of municipalities were highly uneven and fragmented.

Increasingly critical issues included *Leishmania*/HIV coinfections—at a time when the AIDS pandemic was spreading; malnourished children, who present a higher risk of developing severe infection, a fact demonstrated in Bahia by Badaró and colleagues (1985, pp. 77–83); environmental management as a form of vector control intervention; public awareness; and the training of human and veterinary health personnel. Indeed, important threads in this narrative are the expanding involvement of veterinarians in discussions and protocols regarding leishmaniasis, particularly concerning dogs, and the growing influence of animal rights movements (see, for example, Felipe, 2006, pp. 208–229) or, from a more radical stance, animal liberation (Singer, 1975), which brought the pain and suffering of these non-humans to the forefront.

During those same years, AVL ceased to be a rural pathology predominantly prevalent in the Northeast of Brazil, and ATL was no longer exclusively a disease of recently colonized areas linked to deforestation or labor in forest environments. Important demographic transformations underlay this shift. In 1950, the urban population of Brazil accounted for 36.1% of the total population; by 2000, that proportion had reached 81.2% (Girardi, 2008). Incisive analyses were produced at the time linking the geographic expansion and urbanization of leishmaniasis to policies that generated immense economic and social inequalities, driving large contingents of rural populations into *favelas* and impoverished peripheries of cities with precarious infrastructure and sanitation (Benchimol et al., 2025).

The Epidemic in Santarém and the Problem of Dogs

The first urban epidemic of visceral leishmaniasis in northern Brazil occurred in Santarém, a populous municipality in the Lower Amazon heavily impacted by development projects during the civil-military regime. This epidemic shattered the notion that *kala-azar* was a rare and sporadic disease in the region.²⁶

From 1850 to 1920, during the rubber boom, Santarém became, alongside Manaus and Belém, an important node in the riverine circulation of goods and people. By around 1950, it was exporting jute, cotton, rice, corn, and other products. The Trans-Amazonian Highway (BR-230), inaugurated in 1972, intersected with the Santarém-Cuiabá highway (Cuiabá being a city in the state of Mato Grosso)—part of another major road, the BR-163, which would connect southern Brazil to Santarém. These highways and their associated colonization projects attracted thousands of migrants to the region. With the gold rush along the Tapajós River, Santarém became the distribution center of goods for the mining camps (*garimpos*). During the same period, the multinational corporation Cargill installed a grain port in the city, around which soybean monoculture expanded, drawn from Mato Grosso. This accelerated the breakdown of family farming and pushed many families further into the outskirts of Santarém. There, living conditions were precarious, unhealthy, and violent, reflecting the mechanisms of exclusion and segregation that governed the growth of this and other Brazilian cities.

As we have seen, in 1962 Alencar and colleagues identified the first three human cases of visceral leishmaniasis in Santarém. Another case was diagnosed in 1982. In the following year, two more were confirmed; and in 1984, the epidemic erupted in force, triggering an institutional mobilization comparable only to the one deployed in Ceará in the 1950s (Benchimol et al., 2025, pp. 115–246).

For Lainson and colleagues (1984, pp. 1–8), the origin of the epidemic in Santarém was sylvatic, but the concentration of people and dogs in the peripheral neighborhoods allowed the transmission cycle to establish itself in homes and backyards, where dogs and poultry provided abundant blood meals to *Lu. longipalpis*. In reality, cases of visceral leishmaniasis in the region had long been misdiagnosed as malaria, and many children had likely already died under false diagnoses.

The most critical aspect of the campaign in Santarém was the population's resistance to surrendering their dogs to public health authorities. This had already

²⁶ On the epidemics in Santarém and other areas in Pará and Roraima, see Benchimol et al. (2025, pp. 115–246).

occurred in the Northeast, but with less public repercussion. There dogs were initially eliminated with intrapleural ether injections or firearms; later, sodium fluoroacetate (1080), a poison used to kill rodents, was adopted. Strychnine and potassium cyanide were also tested, but these poisons, administered in small balls of cheese or fat, required strict control during application, which hindered the progress of the campaign. Therefore, elimination by violent percussion in the occipital region using a wooden club ended up prevailing (Alencar, 1959, pp. 260–261). According to Francisco Everton Carneiro, a former Sucam employee,

(...) we would conduct canine surveys in 100% of the municipalities (...) the guards arrived at places with authority, asserting themselves. When the owner refused to hand over the dog, they called the police. We killed a lot of dogs. There were dogs with Chagas [disease], and we thought they had *kala-azar*. (...) We would head out in the pickup truck collecting all the positives, and from there we went to a deserted area, dug a pit, then broke [the interviewee strikes the table] and buried them. (Carneiro, Nov. 21, 2017)

At the start of the epidemic in Santarém, according to the test results performed at the Evandro Chagas Institute in Belém, infected animals were eliminated using poison.²⁷ However, a large proportion of dogs lived freely in the streets, especially in the peripheral neighborhoods where backyards were unenclosed. With the intensification of the epidemic, Sucam guards began going out at night to lasso stray dogs and inject them with formaldehyde under the nearest streetlight. As this failed to halt the progression of the epidemic, they resorted to electrocuting the dogs inside a wooden box equipped with copper wires mounted on the back of a pickup truck. They would douse the animals with water and connect the box to the electrical grid, later incinerating the carcasses at the municipal slaughterhouse. These brutal actions were highly unpopular and failed to check the spread of *kala-azar*.

By late 1985, human cases were decreasing, but canine cases were not. In fact, the disease was spreading across an increasingly wide area, a fact that authorities attributed in part to dog owners sending their animals to rural inland areas to protect them, and in part to the population instability in the region. In an edition of the *Jornal de Santarém*, one reads:

Gold panning [*garimpo*], the periodic migration of farmers who alternate between the city and the ‘colonies’ [rural settlements], and the permanent migration of landless rural workers cause a population dynamic in the city unfavorable to the sanitary control of its endemic diseases. A neighborhood visited today will differ a week later due to the

²⁷ The intravenous administration of a potassium chloride solution was combined with Flaxedil, a Rhodia pharmaceutical whose active ingredient, gallamine, acted like curare as a neuromuscular blocker.

presence of new buildings, whether temporary or permanent. (Santarém terá centro de zoonose, March 30–31, 1986, p. 4)

That city in western Pará, near the border with the state of Amazonas, received the visit of Everardo de Carvalho from the National Division of Health Education (DNES) of the Ministry of Health. The meeting he organized in April 1986 was grounded in a document proposing a shift in actions against the disease.

In order to achieve a reduction in numbers in Santarém, it is necessary for the community to be involved in the control of *kala-azar*, rather than relying solely on institutions. (...) It is important that the community itself feels valued by the work and facilitates the operations of the institutions. (Calazar diminuir, mas ainda é grave, 1-9.6.1986, p. 7).

In December of that year, the Ministry of Health convened several specialists in Brasília, the capital of Brazil, to evaluate leishmaniasis control measures. One of its recommendations was:

Community participation is not only desirable but essential to the success of Control Programs for endemic diseases, including *kala-azar*. There is a particularly interesting experience of community involvement (...) in Santarém. This work should be (...) disseminated to other locations. (Marques et al., 1986, pp. 296–301 [299–300])

The guideline coming from “above”—from progressive health professionals holding leadership positions in the Ministry of Health, many of whom were participants in the social movement that would lead to the establishment of the Unified Health System (SUS) two years later—reflected the redemocratization underway in Brazil. Social movements demanded changes across various spheres of social life. In Santarém, as in other Brazilian cities, demonstrations by the National Movement Against the High Cost of Living were taking place. This movement comprised neighborhood groups organized by the progressive Catholic Church, many of which would evolve into Ecclesial Base Communities (CEBs). Galloping inflation deeply affected the working-class population, who were subjected to severe wage compression amid intense income concentration. In Santarém, as well as in other cities, the movement against the high cost of living and mothers' or housewives' clubs fought for neighborhood improvements, highlighted exclusionary urbanization, and offered women an alternative to domestic isolation, prompting them to engage as political actors in the public sphere (Scavone, 2020, pp. 193–227).

In the early 1980s, the Popular Organization Movement (MOP) emerged in a neighborhood of Santarém, taking the fight for healthcare as its primary platform. Similar groups across other neighborhoods led to the founding, in 1989, of the Federation of

Associations and Community Organizations of Santarém (Federação das Associações..., Histórico, n.d.).

In 1986, the National Zoonoses Division of the Ministry of Health entered into 17 agreements with municipal governments across various states to establish Zoonosis Control Centers (CCZs). However, it was not until 1999 that a CCZ was created in Santarém—the first in the Amazon region and only the 113th in Brazil.

During this period, visceral leishmaniasis spread to dozens of municipalities in Pará and Roraima, including among the Yanomami indigenous population. According to Silveira and collaborators (2016, pp. 15–22), this was largely due to deforestation, the immigration of non-immune individuals from other regions of Brazil, disorderly urbanization, the introduction of infected dogs originating from areas where the disease was rampant into non-endemic areas, and also the enhancement of diagnostic methods alongside the expansion of the laboratory network capable of performing them, which made more visible a problem that often went unnoticed.

Controversies regarding dogs in the control of AVL

In Brazil, the transition from the 20th to the 21st century was marked by intense controversies regarding the Ministry of Health measures, which failed to prevent the dissemination, urbanization, and worsening of visceral leishmaniasis across the country.

According to Costa, Pereira, and Araújo (1990, pp. 361–372), the outbreaks that erupted in the 1980s in Teresina, the capital of Piauí, were primarily due to the large contingent of susceptible individuals, the heightened susceptibility of malnourished children, and numerous asymptomatic infections occurring in the shadow of cases that were actually detected and reported. The human-vector relationship might be more significant than that between dogs and vectors. Manson-Bahr (1961, pp. 550–555) was the first to point this out. While investigating immunity mechanisms in Sudan and Kenya, where visceral leishmaniasis was raging in epidemic proportions, he noted that many individuals harbored *L. donovani* without manifesting signs of the disease. Pampiglione later reached similar results in the Emilia-Romagna region of northern Italy (Pampiglione et al., 1974, pp. 348–359; 1974, pp. 447–453; 1975, pp. 60–68).

The extent of asymptomatic seroconversions became clear in Brazil following the studies by Badaró and collaborators (1986, pp. 639–649; 1986, pp. 1003–1011). In the city of Jacobina, in Bahia, they found that there were approximately 18.5 asymptomatic

individuals for every clinically recognized case of visceral leishmaniasis, and that individuals with mild symptoms also went unnoticed.

Costa, Pereira, and Araújo (1990, pp. 361–372 [369–370]) recommended further studies on human infectivity to *Lu. longipalpis* and on potential parallels between Brazilian urban epidemics and Indian *kala-azar*, which occurred without any known animal reservoir. In Ceará, Alencar (1961, pp. 175–180 [175]) considered AVL to be a "zoonosis of canids that is occasionally transmitted to humans", with humans thus playing a minor role in the transmission cycle. The dog was held to be the more significant reservoir due to greater cutaneous parasitism; however, for Leônidas Deane (1958, pp. 431–449), humans could not be discounted as a source of infection, as both were readily fed upon by the vector.²⁸

Attempts made by Adler and Theodor (1935, pp. 516–542) to demonstrate the infectivity of humans to sandflies in the Mediterranean region had failed, but Leônidas and Maria Deane (1955, pp. 61–76) found *Leishmania* in 12 of 81 specimens of *Lu. longipalpis* (14.8%) fed on four out of 14 patients (28.5%) with *kala-azar* in Ceará. Surveys conducted in Brazil showed that the percentage of infected dogs relative to healthy ones was almost always higher than that of sick people relative to healthy individuals; however, because the human population was far larger than the canine population in absolute numbers, the absolute number of parasitized humans exceeded that of dogs (Deane, 1958, pp. 431–449). It is worth noting that, at the time, the full extent of asymptomatic human cases was not known. These uncertainties did not prevent the idea from prevailing that domestic dogs were the primary link in the transmission chain of *Leishmania* to humans in AVL, a conviction that guided the disease control programs not only of the Brazilian Ministry of Health but also of the WHO (see, for example, World Health Organization, Control of the leishmaniasis..., 1990, pp. 27–28).

In his doctoral dissertation defended in 1997 at Harvard University, titled "Could humans be reservoirs of *Leishmania chagasi*?", Piauí-born physician Carlos Henrique Nery Costa began with a troubling observation. The Brazilian program against visceral leishmaniasis relied on the culling of infected (or suspected) dogs, the treatment of human cases, and, to a lesser extent, insecticide spraying—lines of action that had failed to

²⁸ In both reservoirs, sparse blood parasitism complicated disease diagnosis. The frequency and intensity of cutaneous parasitism in dogs and humans were analyzed in Deane & Deane (1955, pp. 61–76; 1962, pp. 198–212 [204]); Prata & Domingues (1956, pp. 541–558); Veronesi et al. (1955, pp. 86–111); Bogliolo (1956, pp. 393–440); Deane (1956, pp. 1–162); Deane & Deane (1957, pp. 225–246); and Prata & Piva (1956, pp. 481–486).

prevent outbreaks in a growing number of cities and with similar intensity in those with and without control measures. This strategy depended on inhumane methods of dog elimination whose efficacy had not yet been unequivocally demonstrated.²⁹

This critique opened the concise communication of the conclusions of Costa's dissertation published in *The Journal of Infectious Diseases* (Costa et al., 2000, pp. 997–1000), which was also co-authored by Jeffrey Shaw, then at the University of São Paulo, and by Costa's two advisors at Harvard University, John David and James Harvey Maguire. In his dissertation, Costa voiced the suspicion that asymptomatic infections in endemic areas constituted a formidable source of parasites to be transmitted to other people.

(...) the identification of even a single infective asymptomatic person would indicate a substantial reservoir of infection given the large number of such persons in the urban environment. Since some of our asymptomatic carriers have acquired infection from a household member with active VL, it is possible that a great number of human infections are acquired from other persons rather than from a canine reservoir. This conclusion supports the view that avoidance of the contact between humans and sandflies should take priority over programs to eliminate dogs to prevent transmission of *L. chagasi* in the Americas. (Costa, 1997, pp. 64-65)

To test this hypothesis, Costa and his colleagues conducted a case-control study in Teresina to estimate the relative risk of contracting the disease in households, using the number of infected individuals and the presence or absence of dogs as variables. They concluded that the risk of acquiring AVL was twice as high in households with dogs, and this risk could be slightly higher given that *L. chagasi* infections were mostly asymptomatic. However,

If dogs were an important or exclusive source of human AVL infection, a clearer correlation between AVL and the presence of dogs would be expected. What is more probable is that the dog (unlike other mammalian reservoirs which introduce the infection from outside, ie., foxes or opossums) is just another victim, which may incidentally encourage the growth and infection rate of domiciliary vector sandfly populations. There are no reports that establish a clear link between human AVL and seroprevalence in dogs, or which show that the killing of infected dogs protects humans from *L. chagasi* infection. (...). Inter-human transmission of AVL also remains a distinct possibility (...). In any event, the Brazilian policy to kill infected dogs should be reevaluated in the light of the present evidence. (Costa et al., 1999, p. 464)

²⁹ According to Costa, the only successful visceral leishmaniasis control program was the one implemented in China following the 1949 revolution, which depended largely on the massive spraying of insecticides (Chung, 1953, pp. 421–464). In Brazil, the areas with lower visceral leishmaniasis incidence were those sprayed for the control of malaria and Chagas disease (Costa, Pereira, & Araújo, 1990, pp. 361–372).

In fact, the first team to raise substantial doubts about the role of dogs in the transmission of LVA was the one that worked in Ceará—precisely the state where the now-questioned control strategy had been implemented. Together with researchers from the Federal University of Ceará (UFC), Thomas G. Evans and Richard D. Pearson³⁰ of the University of Virginia conducted a prospective study of children under 11 years of age in a hyperendemic area of the state located in the municipalities of Itapipoca and Itapajé.

Preliminary data collected in 1986 showed that, in the study area, 24 out of approximately eight hundred children had been treated for *kala-azar* over the preceding four years. They estimated that there were roughly eight infections for every apparent clinical case; thus, if they examined 750 children, they would detect between 100 and 150 seroconversions and approximately 15 to 20 children with overt disease during the three-year study period. Using data from canine serological surveys conducted by Sucam, Evans and his collaborators also studied the relationship between seropositivity in dogs and the development of the disease in humans. By the end of the study, seroconversion was documented in 108 children, yielding a cumulative annual incidence of 4.6%. Twelve of these children (11.1%) developed visceral leishmaniasis, and 96 seroconverted without exhibiting signs of the disease.

According to the authors, geographic factors exerted the greatest influence on these processes. The number of children examined in each zone was equivalent, but the number of seropositive children was markedly higher in the mountain ranges (36, or 3.6% of all tests) than in the foothills (27, or 2.1%), the savannah (21, or 2%), or the town (12, or 1.3%)—a pattern attributed to exposure to a higher density of sandflies or higher infection rates among sandflies (Evans et al., 1992, pp. 1124–1132 [1130]).

Two other already known predictive factors for the development of visceral leishmaniasis were young age and low hematocrit; and indeed, many children were malnourished. Evans's team observed that 50% of the dogs in the mountain ranges and foothills, and 39% of those living in the savannah, had anti-*Leishmania chagasi* antibodies, with parasitological evidence of infection obtained for approximately half of these dogs. They also found that while dogs were present in 61% of households with at

³⁰ Together with Anastácio de Queiroz Sousa, from the UFC, Pearson published a very compelling historical analysis linking the migration of Northeasterners to work in the Amazonian rubber plantations to cutaneous leishmaniasis in their places of origin, to which many subsequently returned (Sousa & Pearson, 2009, pp. 916–921).

least one confirmed case of visceral leishmaniasis, 53% of households with no history of the disease also had these animals. More telling was the fact that human seroconversion rates did not decrease in the periods following dog culling, as would be expected if dogs were indeed the primary reservoir of infection.³¹

Evans and collaborators concluded that children with visceral leishmaniasis were no more likely to have a dog in their homes than their uninfected neighbors. Conversely, children living in households with a prior case of the disease were significantly more likely to test positive than children living in homes with no history of the disease. This could be related to human–sandfly–human transmission, and thus:

Refocusing efforts into surveillance and early treatment of humans in highly endemic, geographically defined areas may prove more cost-effective and result in lower overall human morbidity and mortality than will surveillance and elimination of dogs. (...) Screening of household members of index cases might also be an effective surveillance method. Renewed efforts at local sandfly control during times of most intensive insect reproduction might also serve as a cost-effective and efficacious approach compared to the labor-intensive serosurveys and elimination of dogs. (Evans, 1992, pp. 1124-1132 [1131])

Two years after Costa defended his doctoral dissertation, another study was published by a robust team led by David A. Ashford of the Centers for Disease Control and Prevention in Atlanta (Ashford et al., 1998, pp. 53–57). In Jacobina, Bahia, two peripheral neighborhoods with similar socioeconomic and demographic characteristics were selected for a controlled intervention study. Between June 1989 and May 1993, Ashford and collaborators conducted annual domestic dog censuses in both areas and sought to eliminate all seropositive animals in the intervention area, leaving those in the control area untouched. No vector control measures were undertaken for the duration of the study. The authors concluded that removing seropositive dogs initially resulted in a significant drop in the annual incidence of seroconversion among dogs, from 36% before the intervention to 6% during the first two years of the study. However, over the following two years, the incidence rose to 11% and 14%, respectively. In the control area, the cumulative incidence showed no significant year-to-year variation, fluctuating between 16% and 27%. These findings indicated that removing seropositive dogs could transiently reduce the force of infection transmission among these animals, but was insufficient to eliminate canine visceral leishmaniasis.

³¹ Although studies on the efficacy of dog culling programs were limited—the main reference was still Alencar (1961, pp. 175–180)—by the late 1980s, according to Sucam data consulted by Evans’s team, the number of dogs tested annually in Ceará reached four hundred thousand, with nine thousand seropositive dogs culled per year.

One of the reasons for this was the identification of newly infected dogs during each year of the study—that is, the infected canine population was continuously replenished. Another explanation involved the timing of dog removal. The Irish epidemiologist Christopher Dye (1992, pp. S7–S18) had emphasized two key variables in the transmission dynamics of visceral leishmaniasis: the seasonality of the sandfly population and the number of infected reservoir animals, suggesting that dogs should be eliminated prior to vector population peaks—a strategy that could not be implemented in Jacobina. Ashford and his collaborators reflected on another aspect of the continued incidence of canine *kala-azar*: the influence of other reservoirs, particularly foxes and opossums, roaming near human habitations and infecting sandflies in that environment.³²

The decrease in the mean number of cases among children suggested that removing infected dogs might affect transmission to humans; however, here too, several factors could have influenced this outcome. The study itself may have prompted the population to take greater precautions to prevent *kala-azar*. Furthermore, as there were more cases in the intervention area prior to the start of the study, fewer susceptible inhabitants may have remained. The study's concluding remarks added fuel to the argument of those skeptical of the dog culling strategy.

Although a change in incidence of pediatric cases was observed, we cannot be certain that this was directly related to our dog control program. Regarding zoonotic disease control, interventions aimed at an individual species may be less effective where multiple reservoirs are involved in transmission. Further studies are needed to determine the influence of other potential reservoirs, to understand the course of infection and seroconversion in dogs, and to evaluate the effect of a more efficient removal of infected dogs on both canine and human visceral leishmaniasis. In summary, cost-effectiveness studies evaluating dog control programs are required before national control measures are recommended. (Ashford *et al.*, 1998, pp. 53–57 [56])

A similar investigation was conducted in another region of Bahia where visceral leishmaniasis was endemic: Jequié, in a semi-arid climate zone. Antonio Oliveira dos Santos and collaborators (1993, pp. 583–584) reviewed the city's medical records and found 183 cases of visceral leishmaniasis and 448 of cutaneous leishmaniasis diagnosed

³² Regarding foxes, the main references were the previously discussed studies by Leônidas and Maria Deane and by Lainson and Shaw's team. Concerning opossums, the primary reference was the work of Sherlock, Miranda, Sadigursky, and Grimaldi Jr. (1984, p. 511). Ashford and collaborators cited a short report by Colombian researchers led by Augusto Corredor (1989, pp. 195–197). The cosmopolitan black rat (*Rattus rattus*) had already been implicated as a reservoir for *L. infantum* in the Middle East, but "has not been shown to be important in our area" (Ashford *et al.*, 1998, pp. 53–57 [55]). It is worth noting that Alencar, Pessôa, and Fontenele (1960, pp. 347–348) had published an article on natural infection of *Rattus rattus alexandrinus* by *Leishmania* in an endemic area for cutaneous leishmaniasis in Ceará.

between January 1989 and December 1991. Subsequently, Moacir Paranhos-Silva and collaborators (1996, pp. 39–44) documented a high prevalence of canine infection: 23.5% in a population of 1,681 examined dogs.

In the areas selected for subsequent investigation, no human visceral leishmaniasis cases had been recorded. Paranhos-Silva's team then conducted a cohort study to understand how infection occurred. The urban and suburban areas of Jequié were divided into 140 sectors of 0.25 km² each. The initial cohort consisted of those 1,681 dogs from the previous serological and parasitological study. Seropositive animals were eliminated, and the remaining 1,286 were monitored, with blood samples collected at 6, 12, and 18 months in order to estimate the incidence of infection. All dogs that seroconverted were eliminated. The Bahian researchers determined the rate of canine migration based on the number of animals in each sector during the study period: “The cohort of 1286 seronegative dogs (...) summed up to 1739.7 dog-years of observation. Dog emigration occurred in 15 out of 34 studied clusters” (Paranhos-Silva et al., 1998, pp. 75–83 [79]). For the authors, canine migration could account for the emergence of new foci in non-endemic areas, a factor that ought to be taken into consideration when explaining the progressive urbanization of visceral leishmaniasis in Brazil.

The control measures recommended by the Brazilian National Health Foundation require the screening for *Leishmania* antibodies of all dogs domiciled in areas within an 1 km radius of houses where human cases were reported, followed by sacrifice of the seropositive dogs. (...) The strategy being used is neglecting an unknown, but potentially large, number of infected domiciled dogs, which could serve as reservoir for the reintroduction of the infection into areas previously freed from *Leishmania*-antibody positive dogs. This is made more likely by the fact that dogs in Jequié are seldom confined: they often circulate freely throughout the neighbourhoods (...) The situation is further complicated by the existence of an unknown number of homeless dogs, the majority of which (around 70%) seropositive for *Leishmania* antibodies (...). These facts may easily explain the reoccurrence, described herein, of canine infection in 33 out of the 34 studied clusters (...) despite the elimination of all domiciled seropositive dogs previous to the study as well as those that seroconverted. Indeed, in spite of the elimination of around 15% of the canine population in Jequié by the governmental AVL control program (...) in the last 5 years (...) the number of reported human AVL cases in Jequié has increased steadily (...) 8, 25, 123 and 14 cases in 1993, 1994, 1995 and 1996, respectively. (Paranhos-Silva et al., 1998, pp. 75-83 [81-82])³³

Equally damaging to the official strategy for *kala-azar* control was the study published by Reynaldo Dietze and other researchers from the Federal University of

³³ Another study conducted in Jequié by Moreira Jr. and collaborators (2004, pp. 245–252) demonstrated that the "optimized" dog culling program they implemented in a neighborhood of the city likewise failed to work.

Espírito Santo (UFES), in collaboration with Jason Harris and Ralph Corey, from Duke University (Dietze *et al.*, 1997, pp. 1240–1242). The work presented the results of a 12-month controlled intervention study carried out in Pancas, in the state of Espírito Santo, across three valleys that were adjacent to one another but isolated by mountains. The investigators made censuses and serological surveys among the human and canine populations living in the valleys at the beginning of the study, repeating them six and 12 months later. In two of the valleys, infected dogs were eliminated, while those in the control valley remained untouched. No other measures were taken to control visceral leishmaniasis during the study period. No statistically significant difference was observed among these valleys regarding seroconversion rates during this timeframe. In discussing the results, Dietze and his collaborators stated:

The lack of a difference (...) in the acquisition of human disease between the intervention and control valleys is particularly striking, given the rapid spread of disease that occurred during the study period. (...) If the elimination of infected canines was a potentially effective method for limiting the spread of AVL, its effect should have been detected most readily during such an outbreak. (Dietze *et al.*, 1997, pp. 1240-1242 [1242])

The authors evaluated the factors that could have influenced these results: incomplete elimination of infected dogs was unlikely, as all seropositive animals had been euthanized at the beginning and middle of the study period; on the other hand, the censuses provided no indication of cross-migration of humans or canines between the valleys, and the mountain barriers prevented sandfly migration from valley to valley. Another explanation was the inclusion of primary reservoirs, foxes and opossums, but in general they were neither as abundant as domestic canines nor in such close contact with the human population, thus failing to explain the rising prevalence of the disease in the study area.

These considerations (...) demonstrate that the spread of AVL is not limited by the elimination of infected canines and suggest that human- sandfly-human transmission may have been important in propagating AVL in our study population. It is probable that the role of the human reservoir in the spread of AVL has been underestimated because, until recently, the numbers of infected humans were greatly underappreciated. (Dietze *et al.*, 1997, p. 1242)

Experts are called upon to give their opinion on the control program

The low efficiency of the visceral leishmaniasis control program led the Ministry of Health to convene consultants to re-evaluate it. At the first meeting in Fortaleza, the capital of Ceará, in the late 1990s, the attendees included...

(...) some 20 or 30 people, the *crème de la crème* of those working with visceral leishmaniasis. There were already several veterinarians at the meeting to decide whether or not dog culling should continue. And there I went as the most vehement defender, shall

we say, that the program was unnecessary (...). Odair Genaro was there (...) a vigorous paladin of the program (...). When the discussion ended, a vote was held, and the opinion to put an end to dog culling won. (Costa, 9.6.2022)

During his doctoral studies at the Federal University of Minas Gerais (UFMG) between 1986 and 1993, Genaro produced a thesis on canine visceral leishmaniasis and, alongside other university members, published an evaluation of the serological method then used in canine surveys. The sensitivity of the indirect fluorescent antibody test (IFAT) was 87.5% for diagnosing canine *kala-azar*, but cross-reactivity occurred with tegumentary leishmaniasis in 75% of cases and with Chagas disease in 83.3%. Consequently, positivity rates could not be taken as reliable indicators of canine *kala-azar* prevalence (Costa et al., 1991, pp. 21–25 [21]).

In southern France, Dye and collaborators (1993, pp. 647–656) also investigated the performance of IFAT in detecting canine *L. infantum* infections and concluded that it underestimated the prevalence, incidence, and consequently the scale of the problem to be controlled.

In turn, Marcus Braga and other researchers from the Federal University of Ceará, in collaboration with Evans, conducted a study in an area of São Luís do Curu, a municipality in Ceará where the control program of the National Health Foundation (FNS) had failed to reduce the incidence of human *kala-azar*. It used IFAT as the diagnostic method and euthanized infected dogs, on average, eighty days after the animal's blood was collected for testing. The prolonged presence of the infected dog in the area and the low sensitivity of the test could perhaps explain the failures of the program.

Braga's team then compared, across two areas, the FNS routine with another strategy based on the identification of infected dogs using the Enzyme-Linked Immunosorbent Assay (ELISA), coupled with the removal of infected dogs within a maximum period of seven days. In the area subjected to routine control, there was a 9% decrease in canine prevalence, whereas in the area subjected to the new method, the reduction reached 27%. The authors also verified that only 35.4% of the canine infections detected by ELISA were identified by IFAT; consequently, many infected dogs remained in the area to propagate *L. chagasi* (Braga et al., 1998, pp. 419–510).

In 1994, Genaro took charge of the Leishmaniasis Laboratory at the Central Institute of Biology at UFMG and led several studies on the control and epidemiology of canine visceral leishmaniasis in that state. "Concerned about the expansion of leishmaniasis (...), he ardently advocated for the implementation of control measures

based on the treatment of human cases, vector control, the elimination of infected dogs, and rigorous epidemiological surveillance" (Mayrink, 2002, p. 413).³⁴

Palatnik de Sousa, Genaro, and collaborators (2001, pp. 510–517 [510]) reviewed sixty studies with data on the efficacy of this program and concluded that

1) eradication of the disease in Minas Gerais was achieved by the concomitant use of the three control methods, 2) although seropositivity by an immunofluorescent assay is not completely related to infectiousness, the removal of seropositive dogs leads to a significant reduction of canine and human incidence, 3) improvement of the sensitivity of the diagnostic tool used for canine control should optimize the efficacy of control, and 4) although difficult and expensive, the public health dog control campaigns performed in Brazil reduced the incidence of ZVL and should be maintained since treatment of dogs is an unrealistic intervention, both because of its prohibitive cost and relatively poor effectiveness.

The article was a reaction to the deliberations of the Ministry of Health's consultant committee held in December 2000 in Brasília and presented in the *Revista da Sociedade Brasileira de Medicina Tropical* (Costa & Vieira, 2001, pp. 223–228).

Of the tripod on which Brazil's program to combat AVL was based, the most critical leg became the broad and free distribution of specific treatment, which was crucial for preventing deaths—particularly among the poorest populations, who constituted the majority of the disease's victims. Vector control would be maintained through the application of residual insecticides and, when necessary, spatial spraying. The primary change concerned the canine reservoir.

Based on the previously discussed works, the consulting committee pointed out several weaknesses in this line of action: 1) absence of spatial correlation between the cumulative incidence of human visceral leishmaniasis and canine seroprevalence; 2) absence of significant risk of acquiring VL from cohabitation with dogs; 3) theoretical demonstration that it was an inefficient method compared to vector control and human nutritional supplementation strategies; 4) demonstration that other reservoirs could serve as sources of *L. chagasi* infection—beyond wild canids and marsupials, humans, particularly malnourished children; 5) the high speed at which the canine population was replenished, requiring an impractical proportion and frequency of seropositive dog removals; 6) low efficiency of serological tests in detecting canine infection; 7) absence of clinical or laboratory indicators of canine infectivity for the vector (*ibidem*, pp. 997–1000).

³⁴ Odair Genaro passed away prematurely in Belo Horizonte on March 8, 2002, at the age of 46, as a result of carcinoma.

Reports of successful VL control programs included, alongside the elimination of dogs, vector control using insecticides. The expert committee's references in this regard were limited to studies conducted in the Doce River valley in Minas Gerais (Magalhães et al., 1980, pp. 197–202) and post-revolutionary China's experience (Lu et al., 1955, pp. 91–99; Guan, 1991, pp. 595–601). According to Dantas-Torres (Nov 29, 2016), only Brazil and China carried out such extensive culling of dogs to combat visceral leishmaniasis. And as Benchimol and Jogas Junior show (2020, pp. 503–511), the Chinese experience had served as a near-paradigm for public health officials involved with *kala-azar* in northeastern Brazil during the 1950s. For Costa and Vieira (2001, pp. 223–228), China was now an example of the inadequacy of dog elimination for controlling visceral leishmaniasis. Indeed, Li-ren Guan's more recent article emphasized vector control using insecticides.

The Ministry of Health's consultants recommended that, in the absence of the vector or human cases, the only measures to be taken in areas with canine visceral leishmaniasis should be surveillance and health education. They emphasized the importance of educational programs to better prepare health personnel for human diagnosis and to instruct veterinarians not to treat sick dogs with drugs intended for humans. This practice was deemed inefficient—since treated dogs continued to infect phlebotomines³⁵—and posed the risk of *Leishmania* developing resistance to the medication. The population should be instructed to request that zoonosis control centers examine dogs with suspicious symptoms. Furthermore, the elimination of dogs should be restricted to those with a parasitologically confirmed diagnosis or those from endemic areas who were diagnosed both serologically and clinically (Costa & Vieira, 2001, pp. 223–228 [225]).

Regarding vector control, insecticides should only be applied in households and their outbuildings when human cases were recorded in the area and when at least one of the following criteria was met: 1) the disease had been recently introduced; 2) there had been a clear increase in its incidence; 3) the cumulative incidence exceeded five cases per 100,000 inhabitants per year. When none of these situations occurred, the committee recommended only the intensification of human case-seeking (for potential insecticide

³⁵ Working with six naturally infected dogs, Jorge Alvar and other Spanish researchers (1994, pp. 371–378) evaluated their infectivity to *Phlebotomus perniciosus* before and after treatment with meglumine antimoniate (Glucantime) and Allopurinol (Zyloric). They found that some asymptomatic and symptomatic dogs became infectious to the vector insect months after treatment.

use and early treatment), the training of health professionals in recognizing the disease, and the expansion of vector searches in neighboring areas.

In addition to the three lines of action that had traditionally characterized visceral leishmaniasis control programs, the committee brought a fourth to the forefront: nutritional supplementation for malnourished children, who presented a high risk of severe infection by *L. chagasi*. *Kala-azar* control should thus be coordinated with nutritional programs from other government agencies.

These propositions provoked a strong reaction from supporters of the established visceral leishmaniasis control strategy. The clashes took place primarily within a highly significant scientific forum in Brazil: the annual meetings on Basic Research in Chagas Disease, which began in 1974 and gave rise, in 1997, to the meetings on Applied Research in Leishmaniasis—the former sponsored by the Brazilian Society of Protozoology, and the latter by the Brazilian Society of Tropical Medicine (Colli, 2013, pp. 1–47; Benchimol, Barbeitas, & Jogas Junior, 2026).

The controversy regarding dogs in visceral leishmaniasis remained unresolved, even as research continued to be published that weakened the relevance of animal "euthanasia" during that problematic juncture of the decentralization of vector-borne zoonotic disease control programs.³⁶

Other actors strengthened the movement against dog elimination: in addition to veterinarians and dog owners, non-governmental animal protection organizations and even the industry of products for dogs and other pets. In parallel with these processes, "stable" aspects of the transmission cycles of both tegumentary and visceral leishmaniasis gained unexpected complexity.

Ticks and Other Vectors in AVL

Visceral leishmaniasis was expanding across the coast and the backlands (*sertão*) of Pernambuco, and autochthonous human cases were even recorded in the metropolitan region of the capital, Recife. In the research on this subject, Brandão-Filho relied on the collaboration of a young veterinarian, Filipe Dantas-Torres. As he was beginning his doctorate (2007–2009), Dantas-Torres published "The role of dogs as reservoirs of *Leishmania* parasites, with emphasis on *Leishmania (Leishmania) infantum* and

³⁶ Another study showing that the culling of seropositive dogs did not reduce canine seroprevalence was that by Monteiro et al. (2005, pp. 147–152), conducted in Montes Claros, Minas Gerais.

Leishmania (Viannia) braziliensis", in which he put forward an innovative hypothesis that echoed the one raised by Carlos Costa.

Dogs have long been implicated as the primary domestic reservoir of *Leishmania (Leishmania) infantum*, the etiologic agent of zoonotic visceral leishmaniasis, and there is a growing tendency to view dogs as the primary domestic reservoir of *Leishmania (Viannia) braziliensis*, the most widespread etiologic agent of American tegumentary leishmaniasis. However, insights derived from recent research indicate that the most important domestic reservoirs of *L. (V.) braziliensis* are not dogs, but humans (Dantas-Torres, 2007, pp. 139–146 [139]).

In the interview he granted us, Dantas-Torres (Nov. 29, 2016) explained:

(...) dogs are susceptible, they are in endemic areas, and become infected with various species of *Leishmania*. In most cases, the transmission cycle of tegumentary leishmaniasis remains strictly sylvan. Houses are built at the edge of the forest, where the sylvan cycle takes place, and this cycle often adapts to the domestic environment. In that case, you find a higher prevalence among dogs, but even so, the dog is not considered a reservoir [of the *Leishmania* species causing tegumentary disease]. This is because studies conducted thus far—which are few, I emphasize—show that the dog is a poor source of infection for the vectors. (...) Cutaneous parasitism is not as high as in the case of *L. infantum*. The latter is easily found in visceral leishmaniasis, even in intact skin. For *L. infantum*, dogs indeed represent an important reservoir. But you are not going to control leishmaniasis by eliminating a portion of the infected dogs, because stray dogs exist (...). You eliminate some dogs, others have already become infected.

In his doctoral thesis, Dantas-Torres (2009) analyzed the role of the tick *Rhipicephalus sanguineus* in the epidemiology of canine visceral leishmaniasis, which brings us to another problematic aspect of visceral leishmaniasis control.

As Benchimol and Jogas Junior (2020) show, at the beginning of the twentieth century, a wide variety of hematophagous insects were pointed out as potential spreaders of leishmaniasis. In a report on arthropods of medical importance, Bernard Travis and Renato Labadan (1967) of the U.S. Army Natick Laboratories identified several tick species suspected of being transmitters of leishmaniasis, notably *Amblyomma cajennense* (the star tick), which was considered a potential vector by Richard Strong and collaborators (1915, p. 171) and by Émile Brumpt and Alexandrino Pedroso (1913, pp. 97–136; 1913, pp. 752–762). The latter also suspected *Amblyomma fozzumi*, *A. striatum*, and *Dermacentor variabilis*.

At a time when phlebotomine sandflies were already considered the vectors of Old and New World leishmaniasis, Ítalo Sherlock—then affiliated with the Bahia Research Center of the National Institute of Rural Endemics (INERu), currently the Gonçalo Moniz Institute/Fiocruz–Bahia—considered it likely that there were other transmitters because there were areas in Brazil lacking phlebotomines where canine visceral leishmaniasis was found or predominated. Leônidas Deane had raised the

possibility of transmission through the bites of sick animals, the ingestion of contaminated viscera, or even through coitus (Deane, 1956, pp. 1–162; 1958, pp. 431–449), but to Sherlock, such mechanisms seemed artificial.

Alencar (*Calazar canino...*, 1959) had thoroughly reexamined the subject in his habilitation thesis and concluded that transmission of *kala-azar* by ticks could not be ruled out, though it seemed more likely to him that it occurred via the digestive tract, due to the canids' habit of eating the ticks that tormented them. According to Sherlock (1964, pp. 19–26), there were distinct transmission chains in the disease: dog-to-dog transmission, mediated by *R. sanguineus*; and transmission among humans, from dog to man, and between dogs and foxes via *Lu. longipalpis*. The other transmission processes would be exceptional.

Sherlock's work was cited in Kimberlee McKenzie's doctoral dissertation (1984) at Oklahoma State University, in which she experimentally demonstrated the transmission of canine leishmaniasis by *R. sanguineus*. At UFMG, Maria Teresa Zanatta Coutinho and colleagues (2005, pp. 149–155) also demonstrated (still in the laboratory) the vector competence of this tick. These and other studies are cited in a review published by Vinícius Oliveira et al. (2015, pp. 1622–1628 [1622]):

The disease is generally transmitted through the hematophagous activity of phlebotomine sandflies belonging to the genera *Lutzomyia* (New World) and *Phlebotomus* (Old World) (Murray et al., 2005, pp. 1561–1577). However, alternative routes of transmission have been described in dogs and humans (Turchetti et al., 2014, pp. 403–407). In dogs, there are reports of sexual transmission (Silva et al., 2009, pp. 55–59), vertical transmission (Naucke & Lorentz, 2012, pp. 1–5), transmission via blood transfusion (Freitas et al., 2006, pp. 159–167), and through other vectors such as fleas and ticks that may be involved in the epidemiology of the disease (Moraes et al., 2013, pp. 473–481; the references were completed by me).

On the other hand, LVA's agent had been isolated in other mammal species beyond canids and marsupials (*Didelphis* spp.), such as felines, rodents, chiropters (bats), primates, and more rarely in myrmecophagids (anteaters), equids (horses and donkeys), and South American camelids (llamas) (Roque & Jansen, 2014, pp. 233–273; Rezende et al., 2017, pp. 1799–1807; Caldart et al., 2021, pp. 1–8).

Despite these various possibilities of transmission, controversies surrounding the control of *kala-azar* in Brazil revolved solely around the importance or irrelevance of culling dogs, which are considered the primary amplifying reservoirs (in them, the infectious agent replicates rapidly and reaches high concentrations, thereby increasing its dissemination to other hosts).

The vector also proved to be a more complex problem than it seemed. In Latin America and the Caribbean, AVL had a wide distribution, yet it was associated with a single insect across environments with the most diverse characteristics.³⁷ A small difference in the morphology of *Lu. longipalpis* populations from Pará and Ceará was recorded by Mangabeira Filho (1969, pp. 3–25): the males from Pará presented a pair of white spots on the 4th abdominal tergite, while those from Ceará had two pairs, on the 3rd and 4th tergites. The entomologist from Bahia, who had been part of Evandro Chagas's team, doubted whether they were all of the same species. Lainson and Shaw (1979, pp. 1–116) suggested the existence of a *Lu. longipalpis* complex in order to explain the notable epidemiological differences of visceral leishmaniasis in northeastern and northern Brazil (the Santarém epidemic and the subsequent spread of the disease in Pará had not yet occurred). Differences within *Lu. longipalpis* were later proven, as shown by Benchimol et al. (2025, pp. 395–406). It was shown that it exists in nature as a complex comprising at least three distinct species (Lanzaro et al., 1993, pp. 839–847), including *Lu. pseudolongipalpis* (Arrivillaga & Feliciangeli, 2001, pp. 783–790).

Furthermore, *Lu. longipalpis* is no longer the sole vector implicated in the transmission of AVL. DNA of *L. i. chagasi* was found in specimens of *Lu. migonei* collected in an endemic area of *kala-azar* in northern Pernambuco, covered by tropical forest (Carvalho et al., 2007, pp. 1227–1232; 2010, pp. 108–110). Investigating cases of AVL in La Banda, Santiago del Estero province, Argentina, Oscar Daniel Salomon and collaborators (2010, pp. 84–87) concluded that an enzootic cycle was taking place there with accidental transmission to humans due to this phlebotomine species. *Lu. migonei*—or *Migonemyia migonei*, a genus proposed by Eunice Galati (1995, pp. 133–142)—has a wide distribution in South America, which may also favor the differentiation or speciation of its populations (Rangel & Lainson, 2003; Rangel & Lainson, 2009, pp. 937–954). Other phlebotomine species have been incriminated as vectors of AVL: *Lu. evansi* in Venezuela, Colombia, and Costa Rica; and, most notably, *Lu. cruzi* in Mato Grosso and Mato Grosso do Sul.³⁸

³⁷ In 1977, "this circumstantial incrimination was considerably substantiated through the first experimental transmissions of *L. chagasi* to hamsters subjected to the bites of *Lu. longipalpis*, reared and experimentally infected in our laboratory" (Lainson et al., 1986, pp. 83–124 [90]; see also Lainson, Ward, and Shaw, 1977, pp. 628–630).

³⁸ The hypothesis formulated by Galati et al. (1997, pp. 378–390) and Santos et al. (1998, pp. 315–317) in studies on the phlebotomine fauna of the municipalities of Corumbá and Ladário, in Mato Grosso do Sul, would be demonstrated in several other works on the region discussed in Benchimol et al. (2025).

Dogs from the perspective of new statistical and epidemiological approaches

"Neither the role of dogs in the transmission of *L. infantum* to humans, nor the benefits of eliminating dogs have ever reached a consensus in the literature," wrote Carlos Costa (2011, pp. 232–242 [236]) in a review of the literature produced up to that point on the subject. The impression given by the article is that of a technical tie.

Starting in the 1990s, digital technologies enabled the generation and accumulation of large volumes of data, giving rise to the peculiar expression *Big Data in the Internet of Things*. This required more sophisticated analytical and statistical tools to organize and explore such information and to answer longstanding or novel research questions, such as the spatio-temporal correlations of incidence and/or prevalence rates of human and canine visceral leishmaniasis, or modeling the risk of contracting canine and human infection through the analysis of multiple hierarchical factors. Guilherme Loureiro Werneck and Cláudia Di Lorenzo Oliveira are among the first in Brazil to employ spatial analysis in the service of LVA.³⁹

Oliveira and colleagues (2001, pp. 1231–1239) used inferential statistical models, such as Bayesian methods, for the spatial analysis of the association between cases of visceral leishmaniasis in humans and seropositive dogs in the capital of the state of Minas Gerais, from 1994 to 1997. The geocoding of these cases made it possible to compare, in the same areas, the canine prevalence rates and the incidence rates of the human disease. The authors used the Knox test, based on counting the number of pairs of events occurring within pre-specified critical intervals of time (T) and distance (D), in order to test the hypothesis of the formation of space-time clusters of cases during the examined period. In the selected areas, human cases were overlaid with canine cases using Kernel maps, in which the distribution of points or events (in this case, seropositive dogs) is converted into a "continuous surface of risk" (Brazil. Ministry of Health... *Introduction to spatial statistics for public health*, 2007, p. 44).

Such expressions take us back to the works of two Britons, geographer Anthony C. Gatrell and statistician Trevor C. Bailey. In the article (Gatrell & Bailey, 1996, pp.

³⁹ The extensive case-control study conducted by Carlos Costa in the capital of Piauí was used in Werneck's doctoral thesis, defended at the Harvard School of Public Health under the supervision of James Maguire—who had also supervised Costa: *Spatial approaches to study the epidemiology of visceral leishmaniasis in Teresina* (2000). Oliveira's thesis was supervised by Fernando Augusto Proietti (UFMG) and Ana Diez-Roux (University of Michigan): in Portuguese, *Visceral leishmaniasis in the Belo Horizonte Metropolitan Area: a case-control study* (2006).

843–855) and the book (Bailey & Gatrell, 1995) they published, they provided an inventory of new techniques developed for spatial data analysis that proved to be extremely useful for many research fields and for the formulation of public policies. Softwares were beginning to be developed that allowed the visualization and modeling of geographically referenced data of great value for epidemiological research.

In one of the studies conducted in Teresina, Werneck and his colleagues (2006, pp. 195–201) used remote sensing data obtained by satellite, since

(...) risk factors for infectious diseases operate simultaneously at several levels and ecological data usually are available at different geographical scales (...) Heterogeneity in exposure to risk factors leads to spatial and temporal variability in transmission rates of infectious agents. (...) For instance, on a broad scale, climate and land cover determine the habitat of the vector *Lutzomyia longipalpis* and the size and longevity of its population. At the community level, factors such as land use and quality of housing influence vector populations and their interaction with susceptible persons. At the level of individual persons, young age and malnutrition increase the risk of development of overt VL following infection. The interplay of factors operating at various ecological levels undoubtedly underlies the geographical clustering of cases of VL that has been observed in the Americas and elsewhere. (*ibidem*, pp. 195–196)

Werneck's team used surveillance data collected at various geographic scales and information on the planning and execution of public health actions that also involved multiple layers. This "multilevel modeling" included remote sensing data to map urban space configurations and environmental characteristics, data produced by censuses, and epidemiological data processed with various statistical tools.

In a retrospective study on the AVL epidemic that occurred in Belo Horizonte in the 1990s, Oliveira and colleagues (2001, pp. 1231–1239 [1237]) found "strong evidence that human cases occur in areas where canine prevalence rates are high." The control measures adopted by the Gerência de Zoonoses (Zoonoses Management) had contributed to the drop in human incidence and to the "reduction of the association between the rates." They also observed that there was "space-time aggregation of human cases," that is, the occurrence of a case in a household increased the chances of having another human case in the same household within the following three months (Oliveira et al., 2001, p. 1238).

In the study on the AVL epidemic that occurred in Teresina in 1993–1996, Werneck and colleagues (2006, pp. 195–201) analyzed 1,061 cases distributed across 494 census tracts and 74 districts. The National Health Foundation (FNS) was responsible for control activities at the district level, including canine surveys and insecticide spraying. At the census tract level, the Brazilian Institute of Geography and Statistics (IBGE) collected, processed, and disseminated socioeconomic and demographic information.

Through remote sensing, Werneck and his colleagues obtained environmental information that they combined with data from both levels.

The analysis showed "the importance of interactions between environmental, human, and canine factors in establishing patterns of disease occurrence" (*ibidem*, p. 199). High rates in poor neighborhoods could be the result of precarious living conditions and a location on the outskirts of the city where vegetation density favored vector populations and possibly those of wild reservoir hosts. Malnutrition was also more prevalent in these areas. A high or increasing level of infection in dogs, especially in impoverished areas, immediately before or during the human epidemic, were factors that "strongly predicted a high incidence of [human] VL" (*ibidem*, p. 200). But this did not mean that killing infected dogs reduced human infection rates. Control programs targeted only areas with a high prevalence of canine infection and thus failed to notice areas with low but rising prevalence. The authors pointed out other links between dogs and humans:

It is possible, for instance, that dogs and humans are under the same epizootic pressure, but dogs are more susceptible and develop disease before the human population, and there is no direct connection between infection in the two populations. Although a link between canine and human infection seems more likely, the failure of the strategy of killing dogs to reduce the incidence of human VL supports the need of further research on the role of the infected dog in the transmission of human VL. (Werneck et al., 2006, pp. 195–201 [201])

Benchimol, Barbeitas, and Jogas Junior (2026, pp. 224–226) discuss other studies that do not substantially alter the ambivalent picture presented thus far. Costa and colleagues, including Werneck (2007, pp. 415–419), evaluated the effectiveness of vector control and the elimination of infected dogs on the incidence of *L. chagasi* human infection in Teresina. In Feira de Santana, Bahia, Verena Souza and colleagues (2008, pp. 97–106) compared non-intervention strategies; insecticide spraying; and a combination of insecticide use and the screening and elimination of seropositive dogs. Also in Teresina, Marcos Vinicius Gouvêa et al. (2007, pp. 99–107), including Werneck and Costa, demonstrated that the risk of cutaneous reactivity to *Leishmania*, as assessed by the Montenegro test, was about 30% higher among those who had owned a dog for three years or more. The risk was lower in households with a large number of residents, because "with more people available for [sandfly] blood meals, the individual chance of being bitten by an infected vector would be reduced" (*ibidem*, p. 103). According to the authors, the high level of cutaneous parasitism among dogs, their presence in the peridomestic environment, and potential for transmission supported their epidemiological relevance as a source of infection for humans and other animals. Even so, targeting only dog control

would "probably have a small impact on VL prevention" (*ibidem*, p. 105). In another study conducted in Teresina on household structure and urban services—a neglected target of AVL control programs—Costa, Werneck, and colleagues (2005, pp. 229–236) concluded that the risk of contracting the disease increased significantly for those living in homes lacking sewage systems and garbage collection. Similar conclusions were reached by Elizabeth Moreno and colleagues (2005, pp. 456–463) in an investigation carried out in General Carneiro, Sabará, an urban area in Greater Belo Horizonte, where the population retained rural habits, such as keeping dogs and raising chickens and pigs in their yards.

New Uses for Insecticides: Mosquito Nets and Dog Collars

The impasse regarding the role of dogs in the control of visceral leishmaniasis began to be broken thanks to an innovation that combined the use of insecticides with the animal's health.

Within the group of synthetic pyrethroids developed in the 1970s, deltamethrin became one of the most widely used, including in the control of malaria vectors through insecticide-treated nets.⁴⁰ Deltamethrin is one of the compounds derived from a plant, the *Chrysanthemum*. Pyrethrum, a powder sold in drugstores and used as an insecticide in households and in public health—including in Oswaldo Cruz's campaigns against yellow fever in Rio de Janeiro and Belém at the beginning of the 20th century—was produced from the dried flowers of *Chrys. cinerariifolium* and *Chrys. coccineum*.

Around the time deltamethrin began to be used in bed nets to prevent malaria, Alberto Rocha Falcão and colleagues (1988, pp. 395–396), from the René Rachou Research Center, analyzed the susceptibility of *Lu. longipalpis* to the insecticide. It was a study similar to the one conducted two decades earlier by Falcão on the susceptibility of the visceral leishmaniasis vector to DDT and Dieldrin (organochlorine insecticides), precisely when the global effort to eradicate malaria was failing, partly due to the resistance of its vector mosquitoes to the former insecticide (Falcão, 1963, pp. 411–415). The subsequent study using deltamethrin was motivated by the worrisome resistance to organochlorines (DDT and BHC) in *Phlebotomus argentipes*, the vector of *kala-azar* in

⁴⁰ Deltamethrin was developed by Elliott and colleagues (1974, pp. 710–711) at Rothamsted Experimental Station, a former agricultural research institution in Harpenden, in the English county of Hertfordshire. Insecticide-treated nets (ITNs) were successfully tested in the 1980s in West Africa, by researchers from the Institut Français de Recherche pour le Développement en Coopération-Orstom (Carnevale & Mouchet, 1987, pp. 181–187).

India.⁴¹ The lethal concentration of deltamethrin for *Lu. longipalpis* was two hundred times lower than that of DDT, and a thousand times lower than that of Dieldrin (Falcão et al., 1988, pp. 395–396 [396]).

Carlos Brisola Marcondes and João Nascimento (1993, pp. 15–18) evaluated this in Santa Rita, an endemic municipality in the state of Paraíba. The immediate effects of spraying the walls of houses were "very striking, with high mortality of various harmful arthropods (spiders, cockroaches, centipedes, etc.) and the disappearance of phlebotomine sandflies and culicids, with no evident toxic effects on people and domestic animals" (*ibidem*, pp. 15–16). However, for *Lu. longipalpis*, these effects were short-lived. In Bolivia, by contrast, with a single indoor residual spraying, François Le Pont and colleagues (1989, pp. 223–232) effectively controlled domestic and peridomestic populations of *Lu. longipalpis* in a submontane village in the Nor Yungas province. In Argentina, deltamethrin was successfully tested against *Lu. intermedia*, a vector of ATL, by Carlos Ripoll's team (1987, p. 51).

In the late 1990s, the first tests on protecting dogs using deltamethrin-impregnated collars were carried out by Killick-Kendrick and colleagues (1997, pp. 105–111). It appears that the idea of the collar stemmed from experiments conducted in that decade in China involving "the application of deltamethrin in baths of various dosages, the purpose of which was to impregnate the insecticide into the hair. Side effects in dogs, in addition to the need for frequent baths, stimulated the search for other less harmful procedures" (Bersusa et al., 2018, pp. 1–59 [20–21]).

This search was stimulated by another highly criticized line of action. Mauro Marzochi and other researchers from Rio de Janeiro (1985, pp. 432–446) attempted to treat dogs with *calazar* using Glucantime, but observed a worsening of the general condition of these animals. In Italy, Luigi Gradoni and colleagues (1987, pp. 339–342) found that infection rates in sandflies dropped after they were fed on dogs with leishmaniasis treated with Glucantime, but there were so many reservations about this approach that it proved unviable as a public health measure.

The elimination of all dogs serologically positive for leishmaniasis is not achievable. The killing of dogs should be limited to the severe patent cases only, which usually do not exceed 30-40% of the infected population. Even if these

⁴¹ Dhiman and Yadav (2016, pp. 1–10) provide a review of studies conducted between 1959 and 2015 on the insecticide resistance of *Phlebotomus argentipes* and *Phl. papatasi*, vectors of visceral and cutaneous leishmaniasis, respectively, in Southeast Asia, especially in Bangladesh, India, Nepal, and Sri Lanka.

cases are treated, they remain partially infective to phlebotomines. Treatment should therefore be restricted to asymptomatic and oligosymptomatic dogs detected just before sandfly season. A strong reduction in the sandfly infection rate, as observed during the 4-5 month period following dog treatment, would minimize human exposure to transmission risks. (Gradoni *et al.*, 1987, pp. 339-342 [341-342])

As the Italian researchers already pointed out, and as other authors would demonstrate, the disadvantages of this line of action were mainly three: infected dogs without clinical signs, and thus able to escape diagnosis and treatment, can infect sandflies (Molina *et al.*, 1988, pp. 491–493); the costs of monitoring and treating the dogs are high; and, above all, there is the risk of selecting drug-resistant parasite strains (Gramiccia *et al.*, 1992, pp. 613–620; Killick-Kendrick *et al.*, 1997, pp. 105–111). It is worth noting that an ordinance signed by the Ministers of Health and Agriculture of Brazil would ban the treatment of canine visceral leishmaniasis with products intended for human use or unregistered with the latter Ministry (Brasil. Ministério da Saúde, 11.7.2008).

At Silwood Park, the rural campus of Imperial College London, Killick-Kendrick and colleagues (1997, pp. 105–111) verified that deltamethrin-impregnated collars protected dogs from *Phl. perniciosus* bites for at least 34 weeks. Furthermore, many of these insects died when confined in cages together with dogs equipped with treated collars. The Franco-British team concluded that the use of this device in regions plagued by canine leishmaniasis could lead to a reduction in canine disease and, consequently, in the risk of human infection, but this would not necessarily eliminate the disease in humans and dogs because the parasite could be maintained at a low prevalence in foxes (Killick-Kendrick *et al.*, 1997, p. 110).

It is interesting to read the justifications presented by Killick-Kendrick's team for the experiments they conducted because they lead us to the crisis described pages earlier in the AVL control policies in Brazil.⁴² They were (and continue to be) primarily directed toward reducing the risk of infection in humans.

However, except in western China where canine leishmaniasis and the human disease were eradicated by insecticide spraying and destroying all dogs (Shao *et al.*, 1982, pp. 35-37), the results of control campaigns have been disappointing. Attempts in Brazil to eliminate the reservoir of infection by culling serologically positive dogs (Vieira, Lacerda & Marsden, 1990, pp. 339-340) have met with only limited success. Dye's (1996, pp. 125-130) mathematical models of the options for control strongly suggest that culling is less likely to reduce the incidence of infection than either vaccination, if and when it becomes available, or insecticide spraying in American foci where the vector, *Lutzomyia longipalpis*, (Lutz & Neiva), is peridomestic. As vectors in the Mediterranean subregion,

⁴² The bibliographic references provided by the authors in the citation were completed by me and are listed in the references of this article.

e.g. *Phlebotomus ariasi* Tonnoir and *P. perniciosus* Newstead, are mainly exophagic and exophilic, insecticide spraying of houses in this part of the world is not effective and it is recognized that an alternative is urgently needed (Dye, 1996, p. 125-130). (Killick-Kendrick *et al.*, 1997, pp. 105-111 [106])

Javier Lucientes (1999, pp. 92–94), from the University of Zaragoza in Spain, confirmed the findings of Killick-Kendrick's team. In 2000, a British-Iranian team successfully tested deltamethrin-impregnated collars as repellents against *Phl. papatasi*, the vector of zoonotic visceral leishmaniasis in northwestern Iran (Halbig *et al.*, 2000, pp. 223–226). The following year, the results of an investigation conducted in Gererau, a village near the capital of Ceará, were published. John David and colleagues, including Killick-Kendrick (2001, pp. 839–847), used the deltamethrin collar on four stray dogs, keeping three others unprotected as controls, to see if the device repelled bites from *Lu. longipalpis* and *Lu. migonei* (a vector of *L. braziliensis*, later also incriminated as a transmitter of AVL). The study showed that deltamethrin-impregnated collars protected dogs for up to eight months. If proven equally efficient in the dogs' natural habitat, they would represent an effective and inexpensive strategy for the control of leishmaniasis.

Use of collars should be much more acceptable to the population than the current strategy of killing seropositive dogs. The deltamethrin collars, however, must first be shown to be effective in the field, i.e. they should dramatically decrease the seroconversion of seronegative dogs in the endemic areas. The effect of collaring dogs on the incidence of human cases of VL must be also assessed. The collars could also be used to determine how important the dog is in the transmission of the parasites in various other clinical forms of leishmaniasis where dogs have been postulated to be the natural reservoir host. (David *et al.*, 2001, pp. 839-847 [846])

Another study conducted by Gavvani and colleagues (2002, pp. 374–379) in northwestern Iran demonstrated that the use of this device not only protected domestic dogs but also reduced the risk of *L. infantum* infection in children. For the authors, this method could replace the elimination of dogs, but this would depend on the relative importance in each country of domestic and wild canids as reservoir hosts for the *Leishmania* species responsible for the disease.

A British-Brazilian team led by Richard Reithinger, from the London School of Hygiene and Tropical Medicine, tested this possibility in a municipality in northern Minas Gerais. In September 1999, Reithinger and colleagues (2004, pp. 55–62) initiated a field trial with a cohort of 441 dogs monitored clinically, parasitologically, and immunologically in two neighborhoods of Capitão Enéas. After five months, they verified that collars applied to 136 of 251 dogs in the intervention neighborhood had significantly reduced (by about 50%) anti-*Leishmania* antibody titers during the study period, whereas

this did not occur in the control neighborhood. The discrepancy in the initial and final numbers of the studied cohort was due to the fact that many animals had died or migrated, as well as the loss of collars. Mathematical modeling using these results confirmed that they would be a more advantageous alternative than the elimination of animals as a disease control strategy, but to have a significant impact, complex logistical challenges would have to be faced: achieving high coverage of the canine population with the treated collars, which meant rapid replacement of lost devices, as well as collaring the many new animals entering the local dog population. Furthermore, the effectiveness of the strategy would be compromised in regions where wild reservoirs or stray dogs played an important role in maintaining the endemic disease. Other risks were the development of resistance among sandflies to the insecticide used in the collars or the possibility that the insects might begin feeding preferentially on other *Leishmania* hosts.

The mathematical modeling carried out by Reithinger's team showed that the use of collars would have a greater relative advantage in places where transmission rates of canine visceral leishmaniasis were high; in areas of low endemicity, the impact of the elimination strategy would be greater. Despite these problems, the drastic reduction in the incidence of canine visceral leishmaniasis verified in various surveys led the Ministry of Health to begin distributing deltamethrin-impregnated collars to hundreds of municipalities with high transmission in 2021. Brazil was the first country in the world to adopt this technology as a public health measure for the control of leishmaniasis.

Conclusion

Between 2017 and 2024, there was a significant drop (69.7%) in the emergence of new cases of human visceral leishmaniasis in Brazil, a trend also observed in cutaneous and mucosal leishmaniasis for slightly longer. Even so, the former continues to be present in all five regions of the country, including in urban areas. Between 2015 and 2024, a further 24,454 human cases of AVL were recorded—a severe disease when diagnosis and treatment do not occur in a timely manner. There was even an increase in its lethality and in the proportion of patients co-infected with the human immunodeficiency virus (HIV).⁴³ Experts are still not entirely clear on the reasons for this decline, but among the

⁴³ Brasil. Ministério da Saúde... *Manual de vigilância e controle da leishmaniose visceral*, 2026, pp. 14–15. Rede Interagencial de Informação, *Taxa de incidência de leishmaniose visceral*, 2026; *Taxa de incidência de leishmaniose tegumentar*, 2026... *Semana Nacional de Controle...*, 10.8.2026. The downward trend is also observed in the averages relating to Latin America.

hypotheses being considered (Werneck, 16.8.2026), the use of deltamethrin-impregnated collars figures as a ponderable factor.

The historical review presented in this work shows that the associations proposed for the parasite-host relationship in leishmaniasis have varied greatly since the beginning of the 20th century. Roque and Jansen (2014, pp. 233–273) view this association as a system in which different species play different roles in the maintenance of leishmaniasis, considering each component of the system within a given spatiotemporal scale. "The complexity of the host/reservoir-parasite interaction occurs largely due to the dynamic and unpredictable nature of this constantly changing biological unit, driven by environmental alterations and the coevolutionary process of the components of this interaction" (*ibidem*, p. 234). The present work shows that the relationships between social classes and professional groups, between divergent health policies, and among different cultural representations of humans, non-humans, and the environment also influence the dynamism of this biological system.

As we noted, zoonoses gained growing relevance in studies published after World War II. Until then, the concern of physicians publishing works on leishmaniasis and other diseases was exclusively human beings. Without losing sight of human health, Garnham, Deane, Lainson, and other parasitologists whose works we have discussed felt great empathy for the invader—the organism that parasitized—rather than just for its human host, and they sought to understand the evolutionary dynamics of the host-parasite relationship under increasingly intense anthropogenic pressures. In doing so, they laid the early foundations of a global health paradigm that would come to be called "One Health."

Literature points as a milestone to this the third edition of *Veterinary Medicine and Human Health* by American epidemiologist Calvin Walter Schwabe, who, in 1984, proposed a unified human and veterinary approach to zoonotic diseases, synthesized in the expression "One Medicine" (Cardiff, Ward, & Barthold, 2008, pp. 18–26; *One Health*, 8.6.2018). However, as Roque and Jansen (2014, pp. 233–273 [233–234]) rightly point out, despite changes in the methods used to study domestic and wild animals that host parasites, "even today, the concept of what a reservoir is remains permeated by an anthropocentric view, since a reservoir is frequently referred to as 'the animal species that is a source of infection of a given parasite for man'."

The present work shows that this was—and still is—a territory shaken by intense political, socio-technical, and cultural clashes. For a long time, for the actors involved in preserving public human health, the health of canids was only relevant as a threat to be

exterminated by brutal methods, which have recently been softened thanks to pain-suppressing chemotherapeutic agents and surgical procedures. The new protocols for the euthanasia of dogs and other domestic animals are due, to a large extent, to the (in Brazil, belated) participation of veterinarians in public health.

The history of the campaigns against visceral leishmaniasis presented here shows that the relationship between many of the humans most affected by the disease—the poorest and most marginalized—and their dogs was quite different, with dogs being valued as guard dogs, hunting dogs, herding dogs, or simply as pets. Several examples of the complicity between humans and dogs, and of resistance to the elimination of these animals during campaigns carried out in Brazil, are provided by Benchimol and Jogas Junior (2020), Benchimol and Peixoto (2022), and Benchimol et al. (2025).

In the late 20th century, as leishmaniasis expanded and urbanized, the consensus among scientists and health authorities regarding the necessity or relevance of eliminating infected dogs broke down, and another type of resistance emerged—grounded in scientific studies and, to some extent, in a new set of ideas and values that was spreading primarily among urban social groups.

It was not the objective of this work to analyze the connections between the medical-scientific debate; the growing importance of pets in urban centers, which has even redefined the use of public spaces; the rising influence of animal rights movements, which has brought the sentience and suffering of non-humans to the forefront; and the growing influence of the pet care industry. Lawsuits filed to halt the euthanasia of canine hosts of *Leishmania* stimulated research into prevention and treatment methods available to their "guardians"—a concept that replaced "owner," associated with the construction of the idea of multi-species families. It should be noted, however, that this driving force coexists with very diverse sentiments and behaviors depending on the animal species, ranging from a strong human empathy for dogs to an aversion toward rodents and certain insects. Even so, as Adriana Abreu and colleagues show, based on the case of Porto Alegre, "policies of coexistence are produced and experienced much more from civil initiative, almost always on the margins of and even against public policies conceived and executed by the State" (Abreu, Segata, & Lewgoy, 2020, pp. 103–120; also Abreu, 2020). The interests of the pet industry, combined with pressures from social movements and veterinarians, appear to have been important drivers of the opposition to dog euthanasia and of research into alternative means for controlling these *Leishmania* hosts. It is significant that the first protection tests using deltamethrin-impregnated collars conducted

by Killick-Kendrick and colleagues (1997, pp. 105–111) used devices donated by a pharmaceutical company subsidiary of Hoechst dedicated to animal products.⁴⁴

Other currents of thought have been stirring the ground upon which the One Health paradigm rests: environmental history (Duarte, 2005; Ferri, 5.4.2017) and the history of human-animal relations (Ritvo, 2021, pp. 1–13)—historiographical veins that flourished from the 1970s onward, which, combined with environmentalist movements and their academic production (Benson, 2020), value all forms of life and the agency of non-humans. Ethical theories that problematize our relationship with them (Dorado, 2010, pp. 47–64, 2010; Suárez, 2010, pp. 35–45) and vegan activism (Cáceres, 2024, pp. 217–243) also contribute to the effort to remove humans from the center of the cosmos and renegotiate their relationships with nature (Marras, 2014, pp. 215–260). Another relevant force is the science of animal welfare, taught as an academic discipline for the first time in the 1980s by biologist Donald Broom at the University of Cambridge in England (Manir & Marques, 2024)—the country where antivivisectionism flourished in the 19th century, a movement that today translates into increasingly restrictive legislation on the use of live animals in scientific experiments and into heated controversies regarding the harm this may bring to various scientific fields.⁴⁵

In 2024, a law established National One Health Day in Brazil, to be celebrated every year on November 3, "with the objective of raising society's awareness regarding the indissoluble relationship between animal, human, and environmental health" (Brasil. Lei nº 14.792, de 5.1.2024). This day had been consecrated in 2016 by the international network that supports the One Health movement, which includes the World Health Organization (WHO), the World Organisation for Animal Health (WOAH), the Food and Agriculture Organization of the United Nations (FAO), and the United Nations Environment Programme (UNEP). This network began to be structured after a symposium that brought together health experts from around the world in New York in 2004 to debate the transmission of diseases among populations of humans, domestic

⁴⁴ They consisted of a white polyvinyl chloride (PVC) strip impregnated with 40 mg of deltamethrin. The merger of Hoechst and Rhône-Poulenc S.A. would give rise to Aventis. The impregnated collars would be commercialized under the names ProtectorBands™, by Intervet International, a subsidiary of Akzo Nobel, which in 1999 acquired shares and assets of Hoechst Roussel Vet (Case no. COMP/M.1681 – Akzo Nobel, 22.11.1999); and Scalibor™, by Merck Sharp & Dohme Animal Health (in Brazil: MSD Saúde Animal), the global-scale animal health division of Merck & Co. (Bersusa et al., 2018, pp. 1–59 [21]).

⁴⁵ See, for example, Stagno, 4.5.2026; Khedkar, 4.6.2026 and Sciama, 2026, pp. 34–40. According to this author, among the species used in scientific experimentation, mice predominate by a wide margin (72.4%), and dogs constitute 0.2% of the animals used.

animals, and wild animals. Organized by the Wildlife Conservation Society and Rockefeller University, the "One World, One Health" Symposium approved the Manhattan Principles, recognizing the essential link between human, animal, and environmental health (*One World, One Health*, 29.9.2004).

We can thus consider that the recognition of the role of canids in the transmission cycle of *Leishmania*, the subsequent critique of the elimination of these hosts, and the development of a technique that associated the use of insecticides with the health of these animals as building blocks in the construction of this approach—One Health—which constitutes a *topos* continually redesigned by different currents of thought on the environment, humans, and non-humans.

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Research Data Availability Statement

All data supporting the results of this study have been published within the article itself.

AI usage statement

We used the Gemini AI to assist with translating the text from Portuguese to English.

Conflict of Interest Statement

The author declares that there is no conflict of interest.

Funding / Support

This research was supported by Faperj (Program: "Cientista do Nosso Estado" Program – 2020) and CNPq (CNPq/MCTI Call No. 10/2023 - Track A - Emerging Groups).

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