Chapter 3  Epizootics: Locusts in Argentina and Algeria

While he was awaiting the arrival of his replacement at Chochoh, d’Hérelle turned his restless attention to another matter. At the end of August 1910 (29 August by his later recollection),

a cloud of locusts descended on the little park near my house. My first thought was “if I would be able to find a disease of locusts.” . . . Chance favored me, and what a chance! If, in retrospect, a genie of the thousand and one nights had asked me what sort of insect disease I wanted to study, I would certainly have responded: “a bacterial disease of locusts,” because the locust is a destructive insect designated since the beginning of human-kind as enemy number one, and also because I hoped that governments would call me to use this disease as a means of control, which would give me an opportunity to study the phenomena governing the spread of epidemic diseases. (*PM*, 208)

D’Hérelle’s approach to this new problem followed the same pattern of his previous studies. His first step was to search for sick locusts: he asked the majordomo of the hacienda if he could find any locusts that appeared to be sick while he was out riding around the plantation. To d’Hérelle’s surprise and delight the man returned that evening to present d’Hérelle with a match box containing three dead locusts that he had picked up that day. The majordomo assured d’Hérelle that there were many more to be had if he were interested.

This account of the start of his work on the diseases of locusts is from d’Hérelle’s late memoirs; more contemporary sources suggest a more likely, if less colorful chronology. As early as 3 April 1908, two years before the possibly apocryphal locust hoard, d’Hérelle seems to have been thinking about the locusts. Soon after they arrived in the Yucatan from Guatemala, his wife noted in her diary: “Félix wrote to [undecipherable, possibly Guérin] (coffee) and to Camara (locusts).”

In his first paper appeared on the subject, in the *Journal d’Agriculture tropicale* in August 1910, d’Hérelle, in what was to become his typical style, presented a frontal assault on the existing views of the common disease of locusts. First he reviewed the state of the problem: in some infestations mortality among the locusts is so high that it is possible to scoop up the cadavers in sacks. “This malady resembles which has been previously observed in different countries, notably the Republic of Argentina, and these epizootics [infections of animal populations] have been attributed to the fly related to the genus *Sarcophaga*. He then directly contradicted this conclusion on the basis of his observations: “I have received about fifty dead locusts, have dissected them, and have found the larva of the Muscidae, but only in one out of fifty samples examined: as the larva measures about four mm long, it is impossible that its presence escaped me in forty-nine cases! Furthermore, the forty-nine locusts did not have any interior or exterior lesions: thus the larvae had not escaped. I have arrived at the logical conclusion that supposing that the *Sarcophaga* to be the cause of death of one locust, the cause of death of the other forty-nine was different” (*FDH*: 9). D’Hérelle did, however, observe that the dead locusts consistently had intestines distended with a blackish liquid packed with small bacteria, all morphologically similar. He lamented the fact that all his locust samples had been preserved in alcohol and that the locusts had disappeared from the Yucatán so that he was unable to culture the organisms, but he speculated that the true cause of the epizootic that was killing the locusts was the bacterial infection. Because there are more than thirty species of *Sarcophaga* and they are abundant in the tropics, he considered the flesh-fly maggot as just an incidental parasite, not the cause of the epizootic. He challenged his readers in Argentina to reproduce his observations and was clearly ready for the next locust plague to come his way.

This direct attack on current dogma did not go unnoticed: the journal
editors sent his article to the leading authority on insect pathology, Jules Künckel d'Herculais from the Natural History Museum in Paris. Künckel d'Herculais, in a commentary on d'Herelle's note, observed that because the *Sarcophaga* larvae leave the locust several days before the insect dies and may exit at the small joints between the head and the thorax, the thorax and the abdomen, the ear cavity, or the abdominal rings, "it is therefore not surprising that M. d'Herelle was able to find locusts with no larvae and no apparent lesions." He continued, "In our opinion, the bacteria observed by M. d'Herelle will turn out to be saprophytic bacteria, in the same sense that certain mushrooms are saprophytes, which develop when the locusts are dying or are held in captivity with unfavorable nutrition."

This preliminary note indicates that d'Herelle was interested in locusts earlier than he may have recalled later. This fact also supported by his next paper on locusts, published in 1911. This paper, which turned out to have a major importance to the field of insect pathology as well as beginning d'Herelle's work leading to the discovery of bacteriophage, described the next phase of his study: the isolation of the bacillus from the sick locusts and the demonstration that it is pathogenic for locusts. This work was most likely carried out in the summer of 1910 while he was casting about for projects once the sisal fermentation plant was up and running. Even as he was preparing to leave Mexico, he was looking for opportunities to study locusts. While the family was waiting in Mérida for the ship to France, his two daughters contracted yellow fever and were put under quarantine. At this time, d'Herelle was approached by a Mexican business syndicate to undertake a twofold study related to agaves: modernization of production of pulque (a fermented and distilled beverage derived from agaves) in Mexico and commercial uses of wild agave species growing in the north of Mexico. He was inclined to reject this commission until he came across a recent article in an American journal that attributed recent locust plagues in the southern states to invasions of locust hordes from across the border in northern Mexico.

Undertaking the mission to study pulque production and wild agaves gave him the opportunity and excuse to travel to the north of Mexico, where his personal aim was to look for locusts. While the work for the Mexican syndicate was apparently successful, his search for locusts was not: "From the point of view of locusts it was useless, I did not see a single one." Happily, his daughters had mild cases of yellow fever and completely recovered. They left Veracruz for Paris via New York in February 1911.

In the spring of 1911 the d'Herelle family took up residence in Paris, where Félix "secured work as an unpaid assistant at the Pasteur Institute" (PM, 229). On 22 May Emile Roux, director of the Pasteur Institute, presented d'Herelle's final work on locusts in Mexico to the Academy of Sciences. D'Herelle wrote:

The beginning of 1910 found me in Yucatán, where I observed an epizootic among the locusts (*Schistocerca gregaria*). In all the dead locusts which I saw, I noted the presence in the intestinal tube of numerous cocobacilli which I isolated. I have never found this microbe in the locusts captured in the fields or without the presence of the epizootic, and always, to the contrary, in the dead or sick locusts, infected naturally or experimentally: often then one finds an almost pure culture in the intestines. These experiments serve to demonstrate the pathogenic role of the cocobacillus.

On May 12, 24 locusts were inoculated with one drop of a 24 hour culture in bouillon. A needle was inserted between the second and third anterior ring. All died between 1 and 23 hours after injection.

24 controls were injected in the same manner with one drop of tap water: after 4 days none were dead.

The same one drop of the same culture was deposited with a pipette on the mouth opening of 24 locusts: all died between 10 to 32 hours.

24 controls were again all living 10 days later.

The digestive tube of all the dead locusts contained a blackish liquid or pulp of the specific microbe which was also found in the tissues. An inoculation of this material into bouillon gave in all cases an almost pure culture of the bacillus.

On May 15 I placed 12 healthy locusts in individual dishes with one locust cadaver dead after injection of one drop of culture. Only 2 of the 12 locusts cannibalized the dead insects: one was dead after 9 hours after eating the carcass, the other was dead about 12 hours later. The 10 locusts which had not touched the cadavers were alive 10 days later. In one other experiment 5 of 10 locusts devoured the cadavers and were dead between 7 and 14 hours later. (FedH: 12)

After detailed description of the bacteriological characterization of the cocobacillus (*Cocobacillus sauterelle*, later *C. acridiorum*), and a careful study of its loss of virulence upon passage in laboratory culture and regain of pathogenicity upon repeated passage in the natural host, d'Herelle concluded his paper with a proposal to move from the laboratory to the field, in true Pastorian style: "It will be interesting to try to provoke these epizootics in the countries which suffer locust depredations by means of the bacillus from the Yucatán epizootic." (FedH: 12).

The promise of ending locust plagues was newsworthy enough that d'Herelle's claims were reported in the popular press. There they attracted the attention of Enrique Rodríguez Larreta, a noted man of letters as well as the Argentinian...
Minister to France. By the end of October 1911, d’Herelle and his family were on their way to Argentina. In an arrangement worked out with the government of Argentina, it was planned that they spend half of each year there while d’Herelle organized the battle against the locusts armed with his cocobacillus.

In 1911 Argentina was in the final phase of emerging from the shadow of the nineteenth-century political machine of the conservative followers of longtime president Julio Argentino Roca. The need for reform, especially electoral reform, was widely appreciated. The president from 1910–1914, Roque Sáenz Peña, although a representative of the old conservative order, worked for electoral reform and tried to accommodate the radicals who were continually gaining in influence. This period, from 1906 (the year of the election of Sáenz Peña’s predecessor, Figueroa Alcorta) to the beginning of the war in 1914 and the first popularly elected government in Argentina, was a time of shifting patronage and political alliances. The organization of the Department of Agriculture and the campaigns against the locust hordes were, like most aspects of Argentine life, caught up in these political crosswinds. While d’Herelle came to Argentina with scientific goals, the outcome of his work there, in retrospect, is only fully comprehensible in the context of the rapidly changing political landscape as well as the scientific complexities of his project.

In the late nineteenth century the new sciences of bacteriology and tropical medicine were rapidly expanding in Latin America, partly because national governments were interested in modernization, and partly because colonial governments perceived a need to make the tropics more hospitable for newly arrived European colonists. Not only were Latin American scientists sent by their governments to Europe for training in bacteriology and tropical medicine (Oswaldo Cruz from Brazil, for example, was in Paris from 1896 to 1899), but European scientists were often invited to Latin America to assist with specific projects or to set up local scientific institutes. Félix Le Dantec from the Pasteur Institute in Paris went to Brazil in 1892 to set up an institute of bacteriology in São Paulo and later missions from the Pasteur Institute visited Brazil with the specific charge of investigating the causative agent of yellow fever. In Argentina during the early twentieth century the bacteriological institute of the public health department was headed by an Austrian scientist, Rudolf Kraus.

By a contemporary account, Argentina was an impressive place in 1911: "Buenos Aires is something between Paris and New York. . . . Nowhere in the world does one get a stronger impression of wealth and extravagance. . . . Every visitor is struck by the dominance of material interests and a material view of things: compared with the raking in of money and the spending of it in betting and ostentatious luxury, a passion for the development of the country’s resources and the adornment of its capital stand out as aims that widen the vision and elevate the soul. A recent acute and friendly observer has said that patriotism among the Argentines amounts to a mania.” This commentator, James Bryce, gives a vivid account of the situation in Argentina that led to d’Herelle’s invitation:

Agricultural prosperity, more general than almost anywhere else in the world, is tempered by two risks, either of which may destroy the profits of the year. One is drought. . . . The other danger is a plague of locusts. These horrible creatures come in swarms so vast as to be practically irresistible. Expeditions may be used to destroy them while they are walking along the ground by digging trenches in their path, tumbling them in and burning them, but many survive these efforts, and when they get on the wing, nothing can be done to check their devastating flight. Did the swarms come every year, the land would not be worth tilling, but at present the yield of good years more than covers the losses both of droughts and locust invasions. Men talk of erecting a gigantic fence of zinc to stop the march of the creatures southward from the Gran Chaco [the northern province], for here, as in South Africa, they seem to come out of a wilderness.

The resources devoted to the campaigns against the locusts probably reflected the importance of the Pampa agriculture to the economy and provided a significant opportunity for political patronage. The three major agricultural products of Argentina during this period were wheat, maize, and linseed, and the country ranked first in the export of all three in 1911. The economic progress of the nation was thus highly dependent on the continued development of the Pampas. Bryce observed, “The Pampa country has now been turned from a prairie of grass and flowers into huge fields divided by wire fences and intersected by straight roads, or rather cart tracks, marked by the line of brown dust that a drove of cattle or a vehicle raises.” Most of these large farms (estancias), which averaged six square miles in area, were owned by Argentine-born families of Spanish, English, or German origin. New immigrants from Spain and Italy made up the majority of the agricultural work force.

In response to the need to provide the large farms with protection against the locusts, a rather elaborate organization evolved: "In the Republic of Argentina there exists a special division in the Ministry of Agriculture charged with the destruction of the locusts, this is the Agricultural Defense, which is composed of more than three thousand employees. This administration has as its head the director of Agriculture, and is composed of an inspector-general, of a deputy inspector-general, of three inspectors for each zone, of first and second class
inspectors, of commissioners and of deputy commissioners. In May 1913, it had no less than 200 employees” (FdH: 17, 387 n. i). With such a substantial bureaucracy, it was not surprising that d’Herelle was entering a political thicket when he promised a quick, cheap, and sure cure for the locust problem.

In late October 1911 d’Herelle and his family arrived in Buenos Aires, a thriving city of 1.3 million people at the head of the two-hundred-mile estuary of the Río de la Plata: “Buenos Aires deserves its name, for its air is clear as well as keen, there being no large manufacturing works to pollute it with coal smoke. The streets are well kept and everything is fresh and bright.” While his family stayed in Buenos Aires, d’Herelle went into the central regions, between Chaco in the north and the Pampa in the south, looking for locust swarms. A new system of railways provided access to these major agricultural areas.

His first step was to grow the bacteria in a series of locusts to enhance its virulence after a long period in laboratory culture. He made specific note of the local species of locust and made a point to adapt the coccobacillus to the strain of organism against which it was to be used. When he had a bacterial strain that could kill locusts within six to eight hours, he prepared large bouillon cultures for testing on groups of 250-300 locusts contained in large cages. The cages were infected with a handful of lucerne (Medicago sativa, a clover-like legume) soaked with 20 ml of the culture. Within forty-eight hours the mortality was about 50 percent, and in five days all the locusts were dead. In similar experiments he tested the effect of using infected locusts to spread the disease with similar lethal results. Control cages had only a few dead locusts, which d’Herelle attributed to the trauma of their capture and transport.

On the basis of these demonstrations, the Argentine government decided to allow infections of patches of crickets (the immature forms of the locusts) and flocks of the mature locusts that were then in the Province of Santa Fé. D’Herelle described three limited field tests between 16 and 23 January 1912 and noted that “many other infestations have given identical results” (FdH: 14). These tests were on small plots, some enclosed, between one-half hectare and thirty-five hectares in area. Although the mortality of the land-bound crickets was not to be between 98 and 100 percent, the exact mortality of the locusts could not be determined because they flew in and out of the test area. Even so, “one finds very many dead locusts everywhere on the ground.” Even d’Herelle seemed astonished by the results: “The epizootic spreads with an unprecedented rapidity; a few days after the first infections, the illness was observed in a radius of about fifty kilometers around the first district infected; the specific coccobacillus was isolated from the intestinal contents of the collected cadavers” (FdH: 14). His note, presented to the Academy of Sciences by Roux on 26 February 1912, ended with his usual bravado: “Agriculture in the tropical and sub-tropical countries finds itself henceforth an advantageous measure, without any expense, in the struggle against an insect which has always been considered as a true plague.”

In a longer summary of both the anti-locust campaigns of 1912 and 1913, published later in the Annales de l’Institut Pasteur (FdH: 16), d’Herelle described infections at four sites in the spring of 1912. These trials were rather limited in scope and generally were carried out in one or two days: the first infection was at Escalada in Santa Fé province on 16 January 1912, with the results described above; the second infection was on 22 January at the village of Matilde, also in Santa Fé; on 3 February, two Argentine workers used a culture supplied by d’Herelle from Buenos Aires at Nogoya in the Entre Ríos region and reported that all the locusts were destroyed within three days; the fourth trial was more extensive and took place in the region of Chimalal in La Rioja province, which was heavily infested with crickets. Working by himself at Chimalal between 23 March and 14 April 1912, d’Herelle infected sites more or less at random along the trails and roads, knowing that he could reach only a minority of the insects in the region. Nevertheless, when six inspectors went searching for locusts eight days later, they could find none in the area of Chimalal.

By mid-April 1912 the locust infestation was on the wane, so d’Herelle returned to some experiments already started in July 1911 to see if the coccobacillus could be adapted to kill other insects. While still in Paris he had repeatedly infected a species of small ant and found that it seemed to be susceptible to the bacterium. On a farm near Buenos Aires in January 1912 he tested it on a local species of ant, Seleneopsis gemmifera. In a field with many dispersed ant hills, he infected eight ant hills with a few milliliters of culture each. Within ten days, six treated ant hills were empty of ants. Two months later, the ant hills with an ant hill radius of the first infected hills had no ants. Beyond this distance, the ant hills appeared normal and were full of active insects. It appeared that this species of ant was sensitive to the bacterium even without adaptation to this particular host insect. When this approach was tried with another species of ant, Atta sexdens, no such spectacular results were observed. d’Herelle started passages of the coccobacillus in Atta, an important scourge in many tropical and subtropical countries, in late April and early May, after the locust tests were over. Working in Tucumán with a local entomologist, Lynch Arribalzaga, he increased the virulence of the organism in
one series of experiments and was cautiously optimistic about the eventual biological control of ants as well as locusts (FdH: 16, 325–326).

With the close of the locust campaign, the d’Herelles left Argentina in mid-May 1912 and returned to Paris, where Félix again took up his unsalaried position at the Pasteur Institute. That summer he worked on a curious project: the serologic diagnosis of pregnancy. The reasons for undertaking this work are unclear from both his memoirs and the note d’Herelle later published on this work (FdH: 19). After reading of some work published by the German scientist Emil Abderhalden, d’Herelle may have reasoned that the easily triggered anaphylactic reaction in guinea pigs might be used to assay for the serological reaction between sera from pregnant women and the antibodies raised against placental antigens in sensitized (i.e., immunized) animals. Although this work apparently had little further extensions, his careful approach gives additional insight into his experimental methods: “As I have the habit to be very prudent in experimental matters, with the objective to control my first observations, I requested Latapie who was on Wassermann’s service to give me sera without indicating their origins, each tube simply numbered corresponding to a list which he gave me after the experiments were done.” To his surprise, this test did not seem to be specific for pregnant women, but for female sera in general. “Every serum from a male failed to provoke anaphylaxis, but all the sera from females, even for three girls between ages eight and ten, provoked an intense shock reaction” (PM, 271 bis). This use of a double-blind testing technique—which was unusual for the period—may suggests a level of experimental sophistication and skepticism learned, not by careful apprenticeship with brilliant mentors, but by personal experience over the years.

By October 1912, he was ready to return to Argentina for the next anti-locust campaign. That year the invasions appeared to be less serious than in the previous infestation, and the eggs of the locusts were found in only three regions: Rafaela and Reconquista (two regions of Santa Fé) and Río Cuarto, a region in Córdoba. Again, taking the opportunity to experiment with the situation presented by nature, d’Herelle had different plans for each region. In Rafaela he would infect all the columns of the crickets; near Reconquista, he would infect the crickets just as they started their final metamorphosis to adult, flying locusts; near Río Cuarto, he planned no infections to see if the epizootic from the previous year had any carryover effect from year to year.

The results of this field experiment were reported in the *Annales de l’Institut Pasteur* and strongly confirmed d’Herelle’s belief in the utility of his cocobacillus to control locust plagues (Figure 2). In Rafaela, “practically, the locusts disappeared from the region”; in Reconquista, “throughout the province, the agricultural inspectors estimated the total extent of the invasion to be about 35 hectares, that is to say, the infestation was absent”; and near Río Cuarto, “at the beginning of November I noted the presence of cocobacilli in the cadavers of locusts found dead near the egg-laying sites. In the bands of young crickets hatched in November, one showed the epizootic was present; the mortality was about 60 percent” (FdH: 17, 391).

After a meandering tour into the western and northern parts of Argentina in early 1913, d’Herelle returned to Buenos Aires and then back to France, seemingly confident that his cocobacillus was the answer to future locust invasions. Indeed, encouraging results had started to come in from other regions: cultures sent out from the Pasteur Institute to Colombia, Cyprus,
and Algeria had been used to apparently good effect against locust infestations in those countries.

Two trials in Colombia were carried out in 1913. The locust was the same species as d'Herelle had infected in Argentina, but the utility of the bacteria in the tropical climate was uncertain. In each trial, however, the locust infestations appeared to be controlled by application of the coccobacillus (Fed H: 17, 392–397). In the cases of Cyprus and Algeria, however, a different locust was involved, Sthaurotes marocanus, but laboratory tests showed that C. acridium was pathogenic for this locust, too. Cultures from Paris arrived in Cyprus in February 1913, were adapted to S. marocanus, and then were applied to field trials. Not only did the mortality range between 40 and 100 percent, but the infection appeared to spread rapidly to great distances from the original sites of inoculation (397–398).

D’Herelle became increasing confident in the effectiveness of biological control of insect diseases and spent the summer of 1913 investigating the biology of the coccobacillus. These studies involved tests of animal pathogenicity and appeared to help him refine his ideas about “natural” disease in contrast to “artificial” diseases. He noted that insect pathogens could provoke infections in rabbits, for example, although the rabbit usually was refractory to such infections in nature (PM, 285). What was the meaning of studies, d’Herelle wondered, where animals had infections that occurred only under exceptional laboratory conditions? Were results of such experiments relevant to the infections of the natural host with the same organism? Were these systems not just artifacts of the laboratory? This problem of experimental pathology came to dominate d’Herelle’s thinking and became a point of contention in much of his future work.

As knowledge of his work spread, he began to receive inquiries about other possible insect diseases. One serious problem was a disease of honey bees known as loque or hive sickness. Beekeepers in the region of Paris started to send d’Herelle samples of dead bee larvae from diseased hives. He applied the same approaches to loque as he did to the diarrhea of locusts: by examining the contents of the bodies as well as the surface bacterial flora, he concluded that previous reports that loque was caused by Bacillus subtilis were incorrect and resulted from contamination when the larvae were removed from the hive without aseptic precautions. Instead, he isolated a facultative anaerobic bacterium that he believed caused the disease. Because this work was still incomplete by the time d’Herelle had agreed to return to Argentina, it was suspended and never completed. Later, a fellow Pastorian, Serge Métalnikow, became famous for the study of insect diseases and applying the same approaches as d’Herelle, exploited another organism, Bacillus thuringiensis, as a biological insect control.

In the fall of 1913 the locust plagues in Argentina appeared to be subsiding. Whether this was a consequence of the epizootic of the previous year or natural cyclic behavior was unclear. D’Herelle firmly believed that it was because of his work during the first two campaigns. “The invasion of locusts showed itself to be insignificant, but in contrast, the animosity toward me, on the part of a majority of the Agriculture Defense and the Ministry of Agriculture was singularly pervasive. As in this country [France], it came down to a question of politics, the adversaries of the government raised the question of why a foreigner was being hired in the campaign against the locusts when the invasion had become negligible? And furthermore, it was silly to claim a cause and effect relationship between the infections made during the previous two years and the diminution of the locusts: it was simple coincidence” (PM, 285–287).

D’Herelle requested the reports of the government inspectors that described the effects of the infestations, only to be told that they could not be found. Next, he asked quite bluntly if the Argentine government planned to employ him and his methods; if not, he would not have reason to remain in the country. The Minister of Agriculture requested that he make one final demonstration of the efficacy of his method, and “in a spirit of reconciliation” d’Herelle accepted the challenge. Having found a small patch of crickets in the north of the Santa Fé region, he proceeded to set up the field tests. The government observers who were to judge the test never arrived, however, and an irate d’Herelle returned to Buenos Aires and delivered his ultimatum: “Definitely adopt my procedure or consider my mission terminated.” The answer was evasive: as I have always aimed at clear situations, I postponed my resignation so that I could communicate to the press the motives for it so as to preclude the Minister from giving any false interpretations. And [then] I embarked on the next packet boat” (PM, 287).

The political and scientific consequences of d’Herelle’s activities in Argentina appeared to provoke at least two interesting reactions. First was a scientific review of his work and his methods in general. The Minister of Agriculture appointed a commission of Argentine microbiologists to reevaluate d’Herelle’s results. This commission was headed by Rudolf Kraus, director of the bacteriological institute of the Argentine National Public Health Department; the other members were Dr. Carlos E. Maggio, a bacteriologist from Kraus’s institute, Fernando Lahille, chief of the section of general zoology of the Ministry of Agriculture, and Dr. Demetrio Morales, chief of the bacteriology section of the
Argentine Entomological Institute. Clearly, if d’Herelle was right in sensing xenophobia, this commission was suspect is several ways. The commission obtained a sample of *Cocobacillus acridium* not from d’Herelle, but from the Pasteur Institute. By 1918, however, it was recognized that many of the strains being used in laboratories around the world as *C. acridium* were not identical to d’Herelle’s original isolate, and the characterization of the commission’s strain was not reported in their summary publication. After presenting the results of d’Herelle and others which had appeared in the literature, the commission described its own field tests near Tinogasta in Catamarca and concluded that the “results are completely negative.” Furthermore, they stated their belief that the cocobacillus was a normal inhabitant of the insect intestine, possibly pathogenic when injected in pure culture. For whatever reason, the cocobacillus campaign had come to an end in Argentina.

A second interesting aspect came several years later when Arturo Cancela, a well-known Argentine writer, satirized this episode of science and politics in a novella, *El cocobacilo de Herrlin*. Published in Madrid in 1923 along with two other short works under the title *Tres relatos portentos* (Three stories of Buenos Aires), the novella fictionalized d’Herelle’s work to mock both science and government. D’Herelle appears as a Scandinavian microbiologist named Herrlin, who comes to Argentina at the invitation of the government to rid the country of a plague of rabbits with his pathogenic cocobacillus. Through a bizarre series of mishaps, Herrlin suffers a blow to the head and takes leave of his senses. This loss of memory goes unnoticed, however, by the government bureaucrats who are interested only in the glamour of having a famous foreign scientist in their employ. After many rounds of parties, dinners, speeches, and general hoopla, the campaign against the rabbits appears to be a success: not a single rabbit can be found. Herrlin returns home triumphant, the government takes credit for timely action and wise planning, and the people have known all the while that there were never any rabbits. D’Herelle found this little story “very humorous” and quite accurate as to the political situation (*PM*, 288).

In the spring of 1913, after his return to Paris, d’Herelle again had the opportunity to extend his field trials, this time in Algeria. The Pasteur Institute in Paris was at the center of a rapidly expanding web of overseas Pasteur Institutes (Instituts Pasteur d’Outre-Mer), most directed by former Pastormiers and many overtly related to French colonial interests. These institutes carried out research on local diseases of human or agricultural importance, provided sera and vaccines produced in-house or at the Pasteur Institute in Paris, and often acted as hosts for scientific missions sent from Paris to study specific problems or to help with a local epidemic. In the early twentieth century, most of the missions seemed to be “study” missions, later missions undertook vaccination campaigns and other therapeutic trials, in what Dozon called “Les grandes campagnes d’éradiation.” D’Herelle was clearly in the vanguard of these interventionist Pastormiers. Because of the close administrative and political ties to France, the francophone countries of North Africa, including Tunisia, Algeria, and Morocco, had especially well-developed Pasteur Institutes. They carried on active research and some published their own scientific journals, for example, *Archives de l’Institut Pasteur de Tunis*.

In the spring of 1914 the Pasteur Institute in Algiers invited d’Herelle to visit and participate in their attempts to use his cocobacillus against a different species of locust, *Stauronotus maroccanus*. This North African locust differs from the American locust (*Schistocerca americana*) in that it is much less migratory and less cannibalistic. For several weeks d’Herelle worked with the staff of the Pasteur Institute in Algiers to inoculate regions infested with *Stauronotus* (Figure 3). He considered this trial successful, and apparently so did the Algerian Pastormiers. In 1914 they published two accounts of their studies. The laboratory investigations by Sergent and Lhéritier showed that *C. acridium* could be adapted by repeated passage in *S. maroccanus* to give a highly pathogenic variant. With Béguet, d’Herelle carried out field trials that Béguet later reported as quite promising.

After his return from Algeria in early April 1914, the Turkish government invited d’Herelle to visit Smyrna to help plan for an anti-locust campaign during the next season, the summer of 1914. Always the vagabond, d’Herelle noted that on the way to Smyrna, he stopped for tourist visits in Greece, Constantinople, and Syria. By May he had returned to Paris, only to set off again in July for a visit to Corsica to consult on applications of his locust control method there. The onset of the Great War found him in Vizzavona, on Corsica. On 29 July 1914 he returned to Paris and again joined the Pasteur Institute as an unpaid volunteer, this time in the vaccine department as part of the war effort.

Even with the battle zone nearing Paris, in the spring of 1915 d’Herelle was able to leave his work at the Pasteur Institute and go to Tunisia from 10 April until 1 August. There he worked with the Pasteur Institute in Tunis in further attempts to control invasions of locusts of the species *Schistocerca peregrina*. For three years these locusts had devastated crops in Tunisia, and to avoid famine the government had resorted to loans of cereals to the population. The country was faced with economic disaster, and the government, on the advice of Charles Nicolle, director of the Pasteur Institute in Tunis, decided to augment the
started in his work on locusts and the ideas he so forcefully championed had a life of their own.

While the utility of *C. acridorum* was hotly debated, the biological principles underlying its use had caught the imagination of the scientific community. Several scientists attributed to d’Herelle the first convincing and sustained effort at bacterial control of insect pests: in the 1930s, A. Paillot, a leading French insect pathologist, and Harvey L. Sweetman in the United States, and in the 1940s and 1950s another American, Edward Steinhaus. Although others had isolated pathogenic bacteria from insects before d’Herelle, Paillot and Steinhaus suggest that d’Herelle’s results were sufficiently promising that others joined the field.17 Serge Metalnikov in France and Rudolf Wilhelm Glaser in the United States both carried on extensive research programs based on d’Herelle’s ideas. Metalnikov and his collaborators isolated numerous insect pathogens and in the late 1920s reported that a spore-forming organism, *Bacillus thuringiensis*, discovered in 1913, seemed particularly pathogenic for the corn borer and the gypsy moth, and in field trials they were able to show significant control of insect infestations. This research approach was actively pursued in the 1930s but was made seemingly obsolete by the discovery of insecticidal organic chemicals like DDT. By the late 1950s and 1960s, however, because of the increasing prevalence of pesticide-resistant insects and the concern over the environmental impact of the organic pesticides, research on biological control methods took on new interest. Since then, *B. thuringiensis* has become a major organism used in the biological control of numerous species of insects, and commercial preparations of its spores are readily available in neighborhood garden stores throughout the United States.

Steinhaus suggested that d’Herelle just had the bad luck to isolate a non-spore-forming bacterium:

In light of the inadequate knowledge regarding host susceptibility and resistance, external conditions leading to epizootics, and principles of bacteriology at that time, it is not surprising that contradictory results and claims were made concerning the efficacy of *C. acridorum*. Of course, this does not say that d’Herelle’s successes were all that he claimed them to be. It has been shown (Glaser, 1938) that of the number of strains that existed as *Cocobacillus acridorum*, not all were equally pathogenic, some were not even the same organisms d’Herelle claimed to have isolated, and pathogenicity was difficult to maintain on artificial media without frequent passage through susceptible locusts. Workers condemning the organism used it against locusts only distantly related to *Schistocerca* (which is cannibalistic and migratory). The case of *Cocobacillus acridorum* was a clear example
of the great need for more basic research before the organism as a microbial agent
could be adequately judged.18

While d'Herelle left insect pathology, he still maintained his interest in the
problem of infectious diseases and their uses as biological control agents. Perhaps
influenced by the needs of the war effort, he turned his attention to animal
and human infections. Dysentery and other intestinal infections were a major
focus of interest at the Pasteur Institute in the early years of the twentieth
century, and d’Herelle decided to revisit a problem first discussed in 1900 by
fellow Pastorian Jean Danyzs: the possible use of dysentery organisms to control
infestations of mice.19 In a series of three related studies carried out between
eye early 1916 and the fall of 1918, d'Herelle used Danyzs's bacterium (Salmonella
typhimurium) as a model for gastrointestinal infectious disease. The reasons he
chose this animal model are not explicit in his papers, but his late memoirs
described extensive field work and trials of this bacterium as a biological control
for rat and mouse infestations during the winter of 1918–1919 (PM, 391 et seq.).
This explanation is further supported by his subsequent interest in salmonella
infections of chickens in 1919–1920.

While at first glance d’Herelle’s research pathway appears to be haphazard
and opportunistic, when examined in detail, a continuous path, albeit with
changes in direction, can be discerned. His interest in locusts and their biological
control can be seen to mesh with his wartime vaccine work on dysentery
and the related applications of biological control of rodents. Furthermore, this
approach was firmly sanctioned by the tradition of Pasteur, who had advocated
the use of pathogenic organisms to control the rabbit population in Australia a
generation earlier.20 Further extension of d’Herelle’s interests would soon lead
to his study of epizootics involving avian typhosis and bovine epidemic hemorrhagic fever, this time with a new twist: control a bacterial pathogen by intro-
duction of his newly discovered antibacterial agent, the bacteriophage.

Chapter 4 Bacteriophage

Discovered

In the early decades of the twentieth century, dysentery was a major
research interest at the Pasteur Institute, and with the onset of World
War I the urgency of this work took on even greater significance in
Paris. This research program encompassed both fundamental labora-
tory investigations and their practical medical applications, which
were carried forward in the newly established hospital of the Pasteur
Institute. This hospital was devoted mainly to infectious diseases.
D'Herelle's interests in gastrointestinal diseases of locusts and his work
on B. typhi murium, the bacillus of mouse typhoid, thus fit well within
this institutional program.

Between 20 July and 15 August 1915 ten mounted infantrymen in
the French army along with two young civilian domestics were hospi-
talized with severe hemorrhagic dysentery. These patients, stationed at
Maisons-Laffitte on the outskirts of Paris and only fifty miles from the
stalemate French-German front, were cared for by Dr. Georges
Bertillon. He was sufficiently impressed by the unusual severity of the
disease in these patients to report the clinical features of this mini-
epidemic in the Annales de l’Institut Pasteur (FdH: 22). The micro-

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