
Feature



Carlos Finlay's Life and the Death of Yellow Jack¹

JONATHAN LEONARD²

Yellow Jack." By now we have nearly forgotten the meaning of that name. But a century ago everyone from learned physicians to illiterate urchins knew it well. They knew it came from the yellow quarantine flags or "jacks" used to warn people away from places where yellow fever lurked. And they knew that yellow fever could arrive with little or no warning, strike with devastating force, and claim hundreds or thousands of lives within weeks. So they rightly feared Yellow Jack as a harbinger of rampaging epidemics and mass slaughter.

This fear was sharpened by the symptoms. Those mildly touched by the "black vomit," as yellow fever was sometimes called, would typically experience fever, headache, jaundice, prostra-

tion, and nausea. More severe symptoms included vomiting of "black blood," hemorrhaging, delirium, and death. Depending on the circumstances, a quarter or more of the adults afflicted could expect to die.

Ignorance only increased the sense of peril. Some people knew children in endemic countries tended to get mild cases, and most knew that people who caught yellow fever once were immune to subsequent attack. But nobody knew what caused this disease, how it spread, or how it could be prevented. They only knew that yellow fever was an ancient and well-established scourge in the Americas, and that when it found a large susceptible population—whether in the Spanish Empire's Havana of 1649 or the Memphis, Tennessee, of 1878—it could sweep through like the Black Death. So wherever a severe epidemic surfaced people would flee, bearing the disease with them. In this way yellow fever would appear in some port city and spread outward on a wave of frightened

¹From time to time the *Bulletin* will publish profiles of individuals whose leadership abilities, vision, and dedication enabled them to make outstanding contributions to public health in the Americas.

²Jonathan Leonard is a freelance medical writer and editor of the *Bulletin of PAHO*.

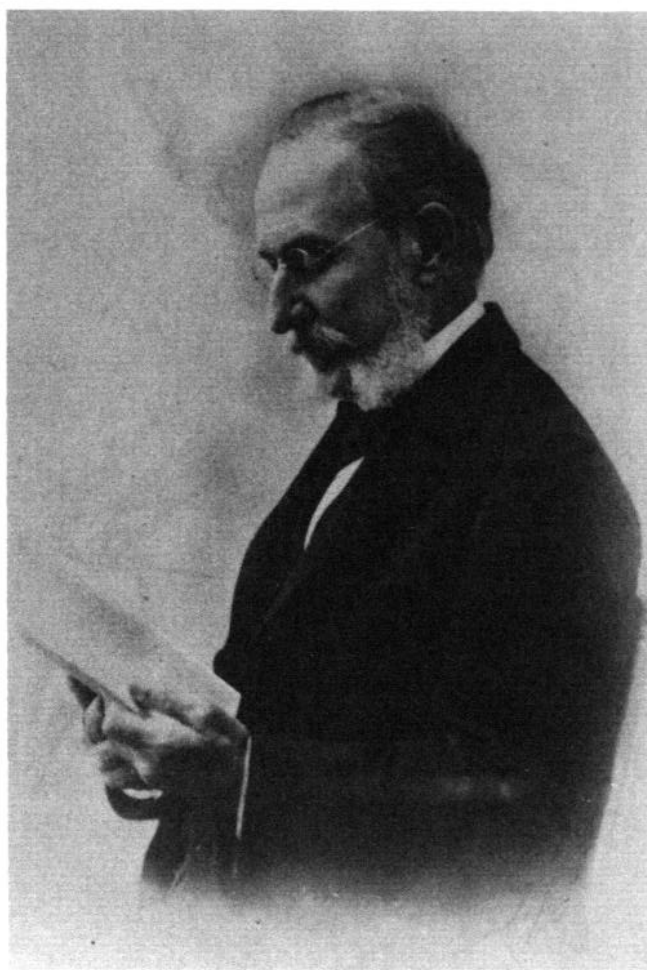
humanity, reaching tens or hundreds of miles inland before it stopped.

Around the turn of the last century, however, this pattern of periodic devastation changed. In 1901 a brisk public health campaign snuffed out the disease in its Havana heartland; similar work freed the besieged U.S. canal-building effort of the scourge across the Panamanian Isthmus; and mopping-up operations elsewhere met with like success. As a result, yellow fever's hold was broken; and while the yellow fever virus was not eradicated (partly because it continued to infect jungle-dwelling monkeys), these events effectively ended yellow fever's reign of terror and the career of Yellow Jack.

The human knowledge that made this possible can be traced back to the summer of 1881. On 14 August of that year a Cuban physician named Carlos Finlay read an extraordinary treatise entitled "The Mosquito Hypothetically Considered as the Agent of Transmission of Yellow Fever" before assembled members of the Royal Academy of Medical, Physical, and Natural Sciences of Havana. He explained how the mosquito now known as *Aedes aegypti* spreads yellow fever by biting infected people, picking up the disease agent, and later inoculating other people with that agent.

This was no half-baked theory. Finlay, then 47 years old, described the mosquito's physiology and habits in detail; revealed the remarkable similarity between temperatures and altitudes maintaining or actively promoting the mosquito and those maintaining or actively promoting the disease; showed how the winged *Aedes aegypti* could account for yellow fever's peculiar epidemiology while inanimate transmitters could not; and presented the results of careful experiments he had performed that appeared to support his view.

Even more remarkable than this the-



Carlos Juan Finlay, 1833–1915 (photograph courtesy of the National Library of Medicine, Washington, D.C.).

ory's accuracy and thoroughgoing nature was its foresight. Finlay, it turns out, launched his theory nearly two decades before its time. The world of public health and serious medical research was simply not yet ready. And so, despite a long succession of published papers from his desk espousing the unfashionable "mosquito theory," as it became known, it was only in 1900 that people with the necessary power and resources began proving his theory right and using it to forge measures capable of quickly defeating the disease.

All this makes it worth asking, Who was Carlos Finlay? Where did he come from? What was the nature of his upbringing, education, personal life, and motivation? Was he simply an investigator in the right place at the right time, or

did he possess qualities that set him apart from others? Above all, What gave him the ability to divine yellow fever's great secret and the tenacity to pursue his theory despite that theory's prolonged and virtually universal rejection by his peers?

FINLAY'S WORLD

Carlos Juan Finlay was born in Puerto Príncipe (now Camagüey), Cuba, in 1833. His father, Edward Finlay, was a Scottish physician who sailed from England as a medical student in the early 1820s to join a British expeditionary force fighting under Simón Bolívar for the Liberation of Venezuela. Shipwrecked, Edward found himself in Port-of-Spain, Trinidad, began practicing medicine there, and married a girl of French descent named Eliza de Barres. They moved to Puerto Príncipe in 1831; and in 1834, the year after Carlos' birth, they settled in Havana. There the elder Finlay practiced medicine, specializing in ophthalmology, until his death in 1872.

In those days Cuba was a Spanish colony. Indeed, it remained Spain's "ever-faithful isle" and last great bastion in the Americas until the Spanish-American War of 1898. Nevertheless, administration of the colony was troubled. Run by a series of governor-generals more or less arbitrarily in the absence of effective control by Spain, the government throughout most of the nineteenth century tended to be ineffective and to confront progressively rising levels of unrest.

This seems unlikely to have been a problem for Carlos Finlay in his youth, because he was rarely home. His father remained inclined to travel after moving to Havana, and Carlos visited various parts of the West Indies and South America with him as a child. Then in 1844, at age 11, he was sent to a French school at Le Havre. Two years later an attack of chorea that left him with permanent

slowness and confusion in expressing himself orally compelled him to return home to recover. Nevertheless, he went back to Europe in 1848, spent time in England and Germany, and subsequently entered college in Rouen, France. There he studied until 1851, when a bout of typhoid fever forced another premature return home—one that deprived him of his college graduation and degree.

Because a Bachelor of Arts degree was required under Spanish law to study medicine, Finlay did not remain long in Cuba. Instead he went to study medicine in the United States—where the standards from the viewpoint of Havana scholars were lower, the rules for admission were relaxed, and no Bachelor's degree was needed.

Happily for his later yellow fever research, he entered Jefferson Medical College in Philadelphia and studied under two men who were father and son—Professor John Kearsly Mitchell, one of the first people to systematically maintain the germ theory of disease, and Dr. S. Weir Mitchell, only four years Finlay's elder, who served as his principal instructor at the college. What Finlay learned from these two was important, especially because an understanding of the role germs play in illness would prove essential to his later work on yellow fever. Furthermore, the Mitchell influence was strong: Weir Mitchell, who later became a well-known physician and author, was both able and coherent, and he and Finlay became fast friends. "I endeavored in vain," wrote Weir Mitchell years later, "to persuade Finlay, who was three years a student in my office—indeed was my first student—to settle in New York where there were many Spaniards and many Cubans. Fortunately, he made up his mind not to take my advice."

The choice may not have seemed so fortunate at first, for soon after returning home Finlay found his career blocked.

The obstacle was an oral examination he had to pass in order to have his medical degree recognized in Cuba. Here his speech problem, the language difficulty imposed by his English-language training, and Havana professors' low regard for U.S. medical education conspired against him. He failed the test on his first try, and thereafter spent a year visiting Peru and other South American countries with his father for motives related partly to medical work and partly to recovery from this setback.

In March of 1857 he took the test again—one of Finlay's hallmarks was persistence—and this time he passed. Later, in 1860–61, he worked at medical centers in Paris acquiring specialized training in ophthalmology. That, however, was the end of his youthful globe-trotting. In 1864, at the age of 31, he established a practice in general medicine and ophthalmic surgery within easy reach of the Cuban capital; and in 1865 he married Adela Shine, a native of Trinidad, and founded a family that eventually came to include three children, and which became well known and well regarded in Havana.

All in all, by the time Finlay settled down he had acquired some surprising talents. An inveterate internationalist, he spoke fluent English, French, and German besides his native Spanish—and he kept in practice. (Among other things, he came to customarily have breakfast in one of his nonnative languages, lunch in a second, and dinner in the third.) Moreover, by growing up in several different foreign cultures he had become familiar with those cultures; and this familiarity, combined with marked congeniality and an ability to get along with people, made him an obvious choice when it came to working with North Americans and Europeans on international health issues.

While getting this international background, Finlay cultivated a remarkably

active and penetrating mind. He was interested in everything. Most of his energy went into things medical; but he also played excellent chess and from time to time explored problems in philology, cosmology, and higher mathematics. At one point he deciphered an old Latin manuscript (he had a good command of that language) and gathered the historic, heraldic, and philologic data needed to show that the bible wherein the manuscript appeared had once belonged to the sixteenth-century Holy Roman Emperor Charles V.

Given this love of intellectual pursuits, it is not surprising that he sought to join Cuba's leading scientific association, the Royal Academy of Medical, Physical, and Natural Sciences of Havana, as a supernumerary member in 1864, the same year he established his medical practice. Partly because he then had no professional reputation in Cuba, his early efforts to join were unsuccessful. But as time passed, colleagues became aware of his abilities; and so, when a chair became vacant in 1872, he was nominated to fill it as a full-fledged member—a nomination that was unanimously approved.

That may have been the Royal Academy's single most productive act. Provided thereby with a forum, Finlay began churning out papers—an average of six a year between 1873 and 1887—on over 30 subjects. His topics included such medical matters as the acclimation and health of Europeans, anesthesia, bandages, cancer, cataracts, cholera, chorea, electrotherapy, leukocytes, leprosy, measles, septicemia, tetanus, and yellow fever—as well as nonmedical subjects like gravity, installation of a bacteriologic laboratory, regulation of gas-lighting, plant diseases, scientific veracity, and the manufacture of soap.

Incredibly, Finlay did nearly all this on his own, without remuneration, in the hours he could spare from his medical

practice and family. He had the long-term help of one colleague, Claudio Delgado, a physician trained in bacteriology; but he had no network of collaborators, teams of assistants, or sources of grant money. Nor did he have a high-powered laboratory. His home housed a clinic for his practice, but most of Finlay's reports to the Royal Academy depended on nothing more than his own keen powers of observation and analysis. In other words, like many other leading thinkers of the nineteenth century, Finlay kept his principal scientific laboratory inside his hat.

Today the world's multibillion-dollar research funding arrangements, acres of gleaming laboratories, and vast stores of accumulated medical knowledge make it very unlikely that one individual could actively command such a wide range of medical subjects. But in Finlay's day both the research support system and medical knowledge were more limited. The germ theory of disease was just beginning to take hold; vaccines, antibiotics, and modern surgical techniques were unknown; and most of the genuinely helpful measures available for diagnosing and treating ailments were relatively simple compared to those available today. So it was still possible for a liberally educated physician with a fine intellect like Finlay's to explore new horizons in many fields.

Not all of Finlay's ideas were precisely on the mark. He was perfectly willing to advance logical theories of unproven merit, and he realized that his ability to test out multitudes of bright ideas was very limited. Therefore, he seems to have presented new theories when he felt them worthwhile—after he had brought them to a point where they appeared ready for discussion, testing, and further analysis by others.

On the whole, however, Finlay's ideas made a lot of sense. For example, consider his work on the dreaded cholera ep-

idemics that periodically struck Havana. By 1867 Finlay apparently knew of public health work in London linking cholera transmission to contaminated water; and, well ahead of most of his contemporaries, he was seeking ways to stop transmission.

When Havana suffered an especially bad cholera outbreak that year, Finlay noted that many of those afflicted were clustered near the Zanja Real, a municipal waterway. On the basis of this observation he wrote a letter to the editor of a local newspaper, *Diario de la Marina*, urging that the Zanja Real be covered over and recommending that people avoid using its waters during the epidemic.

Unfortunately, the official censor felt the letter was critical of what the Spanish Government was doing to combat cholera, and so it was never printed. Some years later, in the early 1870s, Finlay outlined his ideas on cholera transmission in a presentation to the Royal Academy³—which may have proved worthwhile even though it came too late to affect the outbreak.

YELLOW FEVER RESEARCH, 1858–1881

Finlay encountered no such impediments to his work on yellow fever. Historically, that disease appears to have been indigenous to the Americas—notably around Darién, Panama, and Veracruz, Mexico—from the time of the Aztecs. It also spread through the Caribbean, presumably borne by the fierce Caribs or other seafarers, and invaded the island of Santo Domingo soon after its discovery by the Spaniards. (It has been suggested that Christopher Colum-

³Carlos Finlay, Transmisión del cólera por medio de las aguas corrientes cargadas de principios específicos, *Anales de la Real Academia de Ciencias Médicas, Físicas, y Naturales de la Habana* 10:159–170, 1873.

bus may have contracted a nonfatal case of yellow fever on Santo Domingo in 1494.)

Cuba was spared until 1649, when yellow fever arrived, spread, and engulfed the island. The disease slew about a third of Cuba's inhabitants that year and continued its ravages off and on until 1655 when, presumably for lack of victims not rendered immune by previous attacks, it vanished.

For over a century thereafter, like a storybook island under a protective spell, Cuba remained free of the disease. But in 1761 yellow fever struck again. And this time, presumably because Cuba was becoming a major port that received a steady stream of nonimmune immigrants and transients, it stayed.

As a result, in Carlos Finlay's day virtually all native Havana residents were exposed to the disease in childhood; and while some (probably less than 5%) died, the rest were immune for life. The situation was quite different for nonimmune adult newcomers, many of whom perished when exposed. Because of this, antforeign cynics occasionally remarked that "Yellow Jack is our friend," while those who came to Cuba unexposed (and sometimes uninformed in advance of the danger) tended to view their predicament and the disease with horror.

Carlos Finlay said his attention was first drawn to the yellow fever problem in 1858, three years after he finished medical school and one year after he became qualified to practice medicine in Cuba. This seems logical, since his international background and language abilities were likely to have placed him in close touch with immigrants and travelers in peril.

In those days the medical community was utterly at sea regarding yellow fever's cause, with major debates raging between those who believed it to be communicable and those who didn't—groups unimaginatively dubbed the "contagion-

ists" and "noncontagionists," respectively. Finlay initially tried relating yellow fever's prevalence to atmospheric conditions. His first papers on the subject, one published just after his admission to the Royal Academy in 1873 and the other in 1879, were entitled "Atmospheric Alkalinity Observed in Havana" and "Report of the Alkalinity of the Atmosphere Observed in Havana and Other Localities of the Island of Cuba (portion of a report by the Havana Yellow Fever Commission)."

The theory that atmospheric conditions could affect yellow fever's prevalence seemed reasonable then, given the knowledge of the day. But even while his second report was being published in 1879, Finlay's views were undergoing drastic change.

The indirect agent of that change was the United States yellow fever epidemic of 1878. Yellow fever was not generally endemic to the U.S., but in certain summers an outbreak would surface, find the right mix of mosquito vectors and nonimmune inhabitants, and spread fast. The outbreak of 1878, an especially bad one, slew tens of thousands, devastated the cities of New Orleans and Memphis, among others, and reached as far as Galipolis, Ohio, before it stopped.

One way the United States Government responded to this disaster was to send a special commission to Havana to study the disease in its endemic heartland. The six members of this commission included three leading yellow fever experts—bacteriologist George Sternberg, epidemiologist Stanford Chaille, and pathologist Juan Guiteras, as well as a civil engineer (Thomas Hardy), a medical student (Rudolph Mata), and an auxiliary (Abraham Morejón). The six stayed in Cuba a year or so, conducted various activities, and worked with Cuban counterparts designated by the governor-general. Among the latter was Carlos Finlay.

Finlay got on well with the Americans. Years later Rudolph Mata, by then an eminent U.S. health authority, said of this relationship: "In the Hotel San Carlos, the Commission's residence, he [Dr. Finlay] was accepted with the greatest consideration and at the same time with the confidence that is only offered to a close collaborator and appreciated adviser. . . . He was then about 49 years old [Finlay was actually 45 at the time] and he had already become famous as an original, penetrating, tenacious, untiring investigator . . . dedicated to the arduous etiological problem of yellow fever. . . . In my young imagination, Don Carlos symbolized a mentor worthy of imitation by anyone with a dedicated vocation to science and humanity."⁴

Despite all this, any impact that Finlay had on the commission was far less important than the commission's impact upon him. For the commission failed to make obvious progress toward preventing yellow fever or discovering its cause; but it convinced Finlay that atmospheric conditions could not by themselves explain yellow fever, and that the disease was caused by an infectious agent.

According to Finlay himself,⁵ upon receiving the commission's report in 1879 he undertook a review of facts collected since 1853 and deduced the following: First, yellow fever is a germ disease that can be transmitted only under certain topographic and climatic conditions. Second, the disease is not contracted through contact with patients, their secretions, or contaminated air, food, or

drink. Third, pathologic lesions in the capillary walls of yellow fever patients and the hemorrhaging commonly associated with yellow fever suggest that blood vessel walls might prove a good source of the infectious agent.

This caused Finlay to think some special factor was required to transmit the disease agent, and that it was most likely transmitted by inoculation—by taking infectious material from the blood or capillary walls of an infected person and injecting it into the capillaries of someone who was not immune.

"I was thus led to conclude," said Finlay, "that the transmission was effected through the agency of some blood-sucking insect which was peculiar to yellow fever countries. . . . In searching for such an insect I came across the day mosquito of Havana (*Culex mosquito Desv.*, *Stegomyia fasciata* Theo [now known as *Aedes aegypti*]) in which I had observed certain peculiarities in the manner of laying its ova, and in its readiness to renew its bites whenever the digestion of a previous meal of blood had been completed, both of which peculiarities seemed to differentiate it from the other species of gnats and to make it particularly well suited for the purpose of reproducing a disease in an epidemic form. Upon investigation I found that this insect was benumbed and unable to bite under the influence of temperatures of 15 degrees C (59 degrees F) at which degree of cold epidemics of yellow fever were known to cease in New Orleans, Rio de Janeiro, and Havana; and also that after being kept for a while in a rarified atmosphere corresponding to altitudes of four thousand to six thousand feet, at which elevation yellow fever is intransmissible, the insect lost to a great extent the power of driving its sting into the flesh."⁶

⁴Rudolph Mata, *My Memories of Carlos J. Finlay*, in: Ministry of Health and Hospitals Assistance, *Dr. Carlos J. Finlay and the "Hall of Fame" of New York*, Booklet on Sanitation History No. 15, Havana, Cuba, 1959, pp. 85–89.

⁵Carlos Finlay, *Yellow fever: Historical sketch of the disease, its etiology, and mode of propagation*, *Reference Handbook of Medical Science* 8:322–332, 1904.

⁶See note 5 above.

Here was the idea that would ultimately conquer the disease. But Finlay was cautious. The concept ran counter to popular belief, and experimental proof was lacking. So when he was named Cuba's Special Delegate to the 1881 International Sanitary Conference in Washington, D.C., and had cause to address that meeting on the subject of yellow fever, he said nothing about mosquitoes.

Nevertheless, he hinted pretty strongly. That is, he said in his opinion yellow fever transmission required (1) someone ill with the disease within a certain time-frame, (2) a susceptible person, and (3) an agent "entirely independent for its existence both of the disease and the sick man, but which is necessary in order that the disease shall be conveyed from the yellow fever patient to a healthy individual."⁷

That was in February 1881. By the following August Finlay had received authorization to experiment and had begun exposing susceptible people to mosquitoes that had bitten yellow fever patients. The results were encouraging. Of five susceptibles exposed, three soon developed symptoms diagnosed as "abortive" or mild yellow fever.

With this preliminary evidence in hand, Finlay decided to report his findings. Accordingly, on 14 August 1881 he presented the Royal Academy with what would become his most famous work, "The Mosquito Hypothetically Considered as the Agent of Transmission of Yellow Fever." This time he was specific. Besides relating the suspected mosquito's habits to yellow fever transmission and describing his case results, Finlay said:

"Three conditions will be necessary in order that yellow fever may be propagated: 1. The existence of a yellow fever patient into whose capillaries the mosquito is able to drive its sting and to impregnate it with the virulent particles, at an appropriate stage of the disease. 2. That the life of the mosquito be spared after its bite upon the patient until it has a chance of biting the person in whom the disease is to be reproduced. 3. The coincidence that some of the persons whom the same mosquito happens to bite thereafter shall be susceptible to contracting the disease."

In a negative sense, the response to this clear and forthright statement was dramatic. The statement was simply ignored. Few in the audience showed any real interest, nobody asked questions, and virtually nobody but Finlay and his coworker Claudio Delgado followed up. So the response to the most important public health announcement of the decade was one of silence—as if the largest tree in the forest had fallen but no one heard the crash.

Though surprising in hindsight, there are perfectly good reasons why Finlay's announcement fell upon deaf ears. To begin with, in 1881 no insect had been seriously implicated as a person-to-person disease vector anywhere on earth.⁸ Beyond that, not everybody considered yellow fever infectious, and those who did generally believed it to be spread via contaminated objects such as clothing or airborne particles. Finally, Finlay's evidence failed to prove his theory. As he himself remarked, "these experiments are certainly favorable to my theory, but I do not

⁷International Sanitary Conference of Washington, Protocol No. 7, Session of February 18, 1881, p. 34, as reprinted in: Academia de Ciencias de Cuba, Museo Histórico de las Ciencias Médicas Carlos J. Finlay, *Carlos J. Finlay: Obras Completas* (vol. 1), Havana, 1965, pp. 197–198.

⁸Patrick Manson had implicated mosquitoes in taking microfilariae from humans through their bites in 1877; but few if any in Cuba knew about his work, and Manson himself did not go so far as to suggest that infected mosquitoes passed on the microfilariae through their bites.

wish to exaggerate their value in considering them final. . . . I understand but too well that nothing less than an absolutely incontrovertible demonstration will be required before the generality of my colleagues accept a theory so entirely at variance with the ideas which until now have prevailed about yellow fever. . . . My only desire is that my observations be recorded and that the correctness of my ideas be tested through direct experiments."

Given Finlay's own assessment, it is understandable that not much happened. Furthermore, the few who did look twice at Finlay's theory tended to be unconvinced by the evidence at hand. It later turned out that yellow fever transmission was tricky—because an infected person could only pass the yellow fever virus to a mosquito during the first three days of illness, while the mosquito could only pass along the virus after being infected for 12 days. This explains why Finlay's experiments consistently failed to prove his point. It also explains why the influential U.S. health administrator, bacteriologist, and yellow fever expert George Sternberg—a member of the 1879 Yellow Fever Commission and personal friend of Finlay's who later became the U.S. Army Surgeon General—was unable to transmit yellow fever with mosquitoes and why he thereafter gave short shrift to the mosquito theory.⁹

Another reason why Finlay's findings were persistently inconclusive is that Finlay had serious reservations about testing people in life-threatening ways. As a physician dedicated to helping people, he saw nothing wrong with trying to inoculate volunteers against yellow fever by giving them a mild case of the disease. But he was disinclined to perform tests

calculated to produce full-blown yellow fever cases—precisely the kind of tests needed to prove transmission.

Furthermore, we have good evidence that Finlay avoided inoculating his volunteers with mosquitoes that had incubated the infection more than a few days precisely because he feared this might produce severe cases.¹⁰ "It is my belief," he said in an unpublished 1891 article, "that whereas one or two stings from mosquitoes recently contaminated may either occasion in susceptible persons a mild attack or simply confer immunity without any pathogenic manifestations, a severe attack would result from a greater number of such stings and the same might also occur in consequence of a single sting from a mosquito that should have been fed exclusively on sweet juices during several days or weeks after its contamination before it is allowed to sting another nonimmune subject."¹¹

Therefore, he continued to pursue the incorrect theory that mild disease and immunity could be induced through the bites of recently infected insects—for which purpose he inoculated 103 people with exposed mosquitoes between 1881 and 1901, while he correctly avoided using mosquitoes that had incubated the infection for longer times in order to protect the lives of his patients.

This was not all he did. Among other

¹⁰Finlay believed incorrectly that yellow fever germs became lodged in the biting mosquito's mouth parts, and that the infection was transmitted when such germs were dislodged and entered a susceptible person during another bite. Though not understanding about the 12-day incubation period, he felt the germs might multiply in the mouth parts if undisturbed, and that inoculation of a susceptible subject with these more numerous germs might produce more severe disease.

¹¹Obras completas. Translation of C. Finlay (with a preliminary note by J. Guiteras), *Transmission de la fièvre jaune par le moustique culex*, manuscript de 1891 (Transmission of yellow fever by the *Culex* mosquito, 1891 manuscript), *Revista de Medicina Tropical* 4:134–143, 1903.

⁹William B. Bean, Walter Reed and yellow fever, *JAMA* 250(5):659–662, 1983.

things, he kept writing. Between 1881 and 1901, when his theory was confirmed, he wrote over 40 published works on yellow fever, about a third dealing with mosquito transmission. He also kept trying to isolate and identify the agent causing yellow fever, and he provided support and encouragement to colleagues showing interest in his efforts.

More remarkable, building partly upon Ronald Ross' 1897 work describing how mosquitoes transmit malaria, in 1898 Finlay presented a detailed plan for combating both yellow fever and malaria.

"Why should not the houses in yellow fever countries be provided with mosquito blinds, such as are used in the United States as a mere matter of comfort, whereas it might be a question of life or death? The mosquito larvae might be destroyed in swamps, pools, privies, sinks, street-sewers, and other stagnant waters where they are bred by a methodical use of permanganate of potassium or other such substances, in order to lessen the abundance of mosquitoes. But the most essential point must be to prevent those insects from reaching yellow fever patients and to secure a proper disinfection of all suspicious discharges, in order to forestall the contamination of those insects. Well-ventilated hospitals should be built on high grounds, with no stagnant waters or marshes in their vicinity, the doors and windows protected by mosquito blinds, a good system of drainage and sewerage, with facilities for disinfecting all suspicious discharges, and for destroying such mosquitoes and larvae as might be found within the building. Only the upper stories should be occupied by the sick, and none but yellow fever patients and such malaria patients as are immune against yellow fever should be admitted. The examination for admission might be carried out in a separate department devoted to suspicious cases under observation.

"With such hospitals at hand, and an efficient board of health that would see to the proper arrangements for patients who could be left in their homes, and general sanitary improvements in and around the principal cities, there can be little doubt that yellow fever might be stamped out of Cuba and Puerto Rico, and malaria reduced to a minimum."¹²

This plan was quite audacious. At the time of its writing, nearly all of Finlay's colleagues dismissed the mosquito theory; yet here was an entire plan of attack based upon that theory. But even more surprising than this 1898 plan's audacity was its potential; for the general measures outlined were essentially the same as those used a few years later by Major William Gorgas and U.S. health authorities to achieve Finlay's stated ends.

THE DEMISE OF YELLOW JACK

By 1898, of course, major political and military events were fast overtaking Cuba. Discontent with colonial rule had sparked an islandwide revolt in 1895, and Spanish countermeasures—including use of noncombatant detention camps—had produced extreme hardship. As the revolt progressed, it became clear that United States sympathies were with the rebels; so U.S.-Spanish relations became delicate, and when the U.S. battleship *Maine* blew up in Havana Harbor on 15 February 1898, it precipitated the short-lived Spanish-American War and U.S. occupation of Cuba.

Carlos Finlay, then 65 years old, was no idle witness to all this. He was a strong supporter of the rebels, and on more than one trip to the United States he pro-

¹²C. Finlay, The mosquito considered as the agent of transmission of yellow fever and of malaria, *New York Medical Record* 45:737-739, 1899; translation of a paper read before the Academy of Medical, Physical, and Natural Sciences of Havana on 13 November 1898.

vided medical assistance to groups of rebel emigrés.

Indeed, when the Spanish-American War started he was assisting Cuban rebel groups in Tampa, Florida, and from there he went to Washington to volunteer for the U.S. expeditionary force. Not dissuaded from this course by his friend George Sternberg, now the Army Surgeon General, he was named assistant surgeon and joined the expeditionary force's military health service on 22 July 1898. In this capacity he arrived in Cuba soon after the first wave of troops. Working in the Santiago area, he oversaw personnel providing care for the many soldiers afflicted with malaria and yellow fever—deaths from which came to greatly exceed combat losses.

On a broader front, the United States occupation wrought enormous change. The government in charge no longer lacked energy, resources, and organization. Nor was it inclined to accept the yellow fever status quo—especially since the mounting epidemic was selecting multitudes of nonimmunes within the expeditionary force as its prime victims.

Even so, linking up with the mosquito theory took a while, and the first major public health efforts in Havana were directed at sanitation.

It is easy to understand why. Shortly after the U.S. occupation, a Typhoid Fever Board whose members included military surgeon Walter Reed demonstrated that unsanitary conditions ("flies, feces, fingers, and filth") rather than impure milk or water were responsible for spreading typhoid fever within the occupying army's encampments. No small matter (five times more U.S. soldiers died of typhoid fever than died in battle), this finding led to a heroic cleanup effort directed at both typhoid and yellow fever.

The campaign, ably directed by Major William Gorgas of the U.S. Army Medical Corps, practically eliminated typhoid

fever but failed to deter Yellow Jack. According to Gorgas, "As the immune population increased, the disease steadily increased, in spite of all our sanitary efforts, and the end of 1900 saw Havana in the clutches of one of her severe epidemics of yellow fever." Obviously, the situation demanded a new approach.

Meanwhile, researchers investigating the cause of yellow fever had been on the trail of a red herring. Guiseppi Sanarelli, an Italian bacteriologist working in South America, had mistakenly identified a bacterium he called *Bacillus icteroides* ("jaundice-producing bacillus") as the true cause of yellow fever. In 1898 the U.S. Army appointed a two-man yellow fever commission to investigate this claim. Their report supported Sanarelli but failed to convince Surgeon General Sternberg, who was skeptical of Sanarelli's claims. Sternberg therefore dispatched assistant military surgeon Aristedes Agramonte to Havana to review the commission's work, and followed this up by forming a new commission headed by Walter Reed, who arrived in Havana on 25 June 1900 to continue the yellow fever work.

This new four-man commission consisting of Reed, Agramonte, and two other assistant surgeons—James Carroll and Jesse Lazear—quickly ruled out Sanarelli's organism as the cause of yellow fever—and thereby ran out of promising theories. They knew that Sternberg rejected the mosquito theory, and only one commission member (Lazear) had any enthusiasm for it. Nevertheless, the other avenue of research open to them (comparative study of the intestinal flora of yellow fever patients) seemed so unpromising that they decided to go ahead and examine Finlay's concept.

They therefore visited Finlay, who welcomed their inquiries, gave them copies of his published works, and provided eggs of the mosquitoes used in his re-

search. The commission then hatched the eggs, reared the mosquitoes, and used them to carry on.

Experiments with human volunteers—including the commission's own members—began in August 1900. At first the results were disappointing. None of those bitten by supposedly infected mosquitoes contracted yellow fever. But the work went on, and in September a soldier named William Dean and two of the commission members—Carroll and Lazear—developed yellow fever. Carroll, who was highly skeptical of the mosquito theory, and Dean contracted well-marked cases but recovered. Lazear, the only commission member who favored Finlay's theory, developed a severe case and died.

Reed, who had been in Washington and who had previously expressed disdain for the mosquito theory, rushed back to Havana—only to learn that the cases did not afford convincingly proof of the theory. Both Carroll and Lazear could conceivably have been exposed to yellow fever in other ways; and Dean's case, by itself, was insufficient to provide absolute proof to a highly skeptical expert community. However, Reed and the other surviving Commission members were convinced; and having determined that an incubation period of about 12 days was required before an infected mosquito could pass the disease on to a new victim, they were in a position to proceed.

Reed therefore devised a series of elegant and carefully controlled experiments in which human volunteers not otherwise exposed to yellow fever were exposed either to infected mosquitoes or to fomites of yellow fever patients.

The final series of tests, conducted in November and December 1900, had seven nonimmune volunteers sleep for 20 nights in the disgustingly foul bedclothes, clothing, and discharges of yel-

low fever patients. None got yellow fever. Two other nonimmune volunteers slept in a building with infected mosquitoes for 18 nights protected from the insects by wire screens; neither of them got yellow fever. Finally, one volunteer was briefly exposed to the infected mosquitoes in the screened building for three days in succession. On the fourth day he developed an unmistakable case of yellow fever.

Even these conclusive results did not convince the medical community at large that Finlay had been right. But they convinced the Military Governor of Cuba, General Leonard Wood, himself a member of the Army Medical Corps. Wood promptly set Gorgas off on a new kind of campaign with four principal aims: keep people without immunity to yellow fever outside Havana; quarantine yellow fever cases promptly and isolate them from mosquitoes; eliminate all adult mosquitoes in the vicinity of yellow fever patients; and eliminate *stegomyia* (*A. aegypti*) larvae throughout the city. As may be seen, these measures were very similar to those Carlos Finlay had recommended in 1898.

Partly because the steps involved were well-planned and effectively executed, the result was decisive. In 1900, before the campaign started, there were at least 300 deaths from yellow fever in Havana. During the whole of 1901 only 18 deaths were reported, and by the end of September yellow fever had disappeared. Furthermore, elimination of the great endemic in Havana caused the disease to die out in other parts of Cuba and greatly reduced the outbreaks arising from imported cases elsewhere in the Caribbean as well.

Obviously, this campaign did not defeat yellow fever everywhere. But it provided the blueprint for eliminating epidemics in Panama during construction of the canal there, effectively combating the

last major New Orleans outbreak in 1905, and thereafter exorcising the yellow fever demon wherever it appeared. So finally, 20 years after Carlos Finlay described his theory, his deductions broke the back of the disease.

Finlay's work did not stop there. In 1902, after the United States occupation ended, he became Chief Health Officer of Cuba and President of the Board of Health. From these posts he oversaw the start of nationwide vaccination against smallpox, creation of maritime health regulations, and the drafting of Cuba's first sanitary code. He also took a personal hand in innovative work that greatly reduced the death toll from neonatal tetanus; and he continued to produce writings on yellow fever and other subjects. In 1908 he retired from public life, and seven years later, on 20 August 1915, he died peacefully at the age of 82.

The endurance that characterized Carlos Finlay's mosquito theory, contribution to public health, and life contrasts sharply with the fate of the Reed Commission's three U.S. members. Lazear, as already noted, died of yellow fever in 1900; Reed himself died of appendicitis in 1902; and Carroll died of endocarditis in 1907—four years after expressing the opinion that Finlay had done little and Reed deserved the laurels, a sentiment that found scant support among the surviving principals involved.

In retrospect, considering the importance of yellow fever's demise and the diverse groups responsible, it is understandable that some squabbling should ensue over who got credit. For clearly, Finlay was not alone. The conquest of yellow fever depended upon the Reed Commission's genius for careful and compelling research, the presence of plentiful resources, and William Gorgas' organizational legerdemain. If circumstances had not conspired to provide

these other ingredients, conquest of yellow fever would have had to wait.

Furthermore, there is good reason to think the time for implicating the mosquito had arrived. Carlos Finlay was the first person to seriously postulate direct disease transmission by mosquitoes from man to man. But four years earlier, in 1877, mosquitoes were implicated by Patrick Manson in transmitting filariasis—supposedly by taking in microfilariae with blood and dying in water that could infect people who drank it. And in 1897 Ronald Ross convincingly explained how malaria is transmitted by the *Anopheles* mosquito. In hindsight, it seems clear that once the germ theory of disease had emerged, it was only a matter of time before the germs' insect vectors would be unmasked.

But hindsight was not available to Finlay, and solving the riddle of yellow fever transmission was not simple, any more than Manson's discovery was simple. Furthermore, if Finlay's theory had not preceded the occupation of Cuba, events could have been quite different. As William Gorgas said in a letter to Finlay on 12 August 1910, "I believe that it was through your work and personal advocacy of the mosquito theory that the American Board, of which Reed was Chairman, was induced to investigate the mosquito theory, and that if you had not done the work which you had already done along these lines in 1900 the American Board would never have undertaken the investigation of the mosquito theory."¹³

Perhaps the most basic reason why Finlay accomplished all he did is that he

¹³William C. Gorgas, letter to Dr. Carlos J. Finlay, in: Ministry of Health and Hospitals Assistance, *Dr. Carlos J. Finlay and the "Hall of Fame" of New York*, Booklet on Sanitation History No. 15, Havana, Cuba, 1959, p. 73.

brought together in his person most of the skills needed by a modern international public health organization. He had the languages, the multicultural background, the general knowledge, the medical education, the diplomatic ability, the intellectual curiosity, and the desire to help that are the essential ingredients for fine work within this field. In this light it seems somewhat less surprising that he played an unusually large role in the international public health efforts of his time, or that his work still stands as a model of excellence today.

Of course Finlay, like Manson, did not have all the keys to the puzzle. Most notably, he was wrong about being able to induce immunity with recently infected mosquitoes. But he understood yellow fever and its insect vector well enough to be reasonably sure his mosquito theory was correct and to stay ahead of his time for 20 years.

It should also be remembered that Finlay did his yellow fever work on his own hook. He had no military organization to support him, no squads of health workers to direct. Instead, he was one of those broadly educated men who led through intellect and who helped to expand nineteenth century medical horizons in an age when modern medicine was young and when people everywhere knew Yellow Jack as a mysterious bedevilment and holy terror.

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