Endemic Yellow Fever and Immunization in Sub-Saharan Africa[1]

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Introduction

Yellow fever is a highly fatal, incurable viral infection. Not all who are bitten by an infected mosquito develop symptoms but many of those who do experience fever, headache, pain, nausea and dizziness over a period of three to six days at which point they recover and are thereafter fully immune. Less fortunate are those who develop the classic symptoms of yellow fever. Following a brief period of remission, the onset of classic yellow fever is signaled by the return of high fever together with nausea and vomiting. It is at this point that the more frightening symptoms of jaundice, kidney failure and hemorrhage appear, leading at times to the black vomit or *vomito negro* for which the condition was once known. As an incurable infection, physicians can do very little for people suffering from yellow fever and half of those who develop severe symptoms experience shock, seizures and become comatose before dying. This high mortality and lack of effective treatment make the return of yellow fever a fearful prospect and explain why it was once a terrifying disease. In the Americas, yellow fever was, for a period of several hundred years, an unrelenting source of epidemics causing significant loss of life and

endless commercial disruption. Efforts to eradicate yellow fever following the early 20th century discovery of the mosquito vector and mass vaccination in endemic regions of South and Central America brought an effective end to "New World" epidemics. The same, however, cannot be said for Africa.

Since the middle of the 20th century epidemic outbreaks have been confined almost exclusively to Africa, where 90 percent of all yellow fever incidence reportedly occurs. As yellow fever was originally from Africa, only crossing the Atlantic together with enslaved populations and one of yellow fever's primary mosquito vectors, its ongoing impact in Africa might be seen as an inevitable feature of the African environment. Moreover, this view of Africa as inherently diseased has a long history and yellow fever played a significant role in the high European mortality that made West Africa the "white man's grave." A historical analysis of the ongoing public health threat of yellow fever in Africa is lacking and long overdue. This paper represents a preliminary examination of that history based solely on archives held at the Rockefeller Archive Center concerning the period from 1920 until the close of the Second World War. It provisionally argues that the high burden of yellow fever in Africa and especially the unequal burden of yellow fever from mid-century was far from inevitable. Instead, it represents a failure of colonial medicine and global health –albeit, hopefully, a temporary one.

The Rockefeller Yellow Fever Commission and Immunity Surveys in Africa

In 1920, on the heels of the apparent eradication of yellow fever from key urban and commercial centers in the Americas, the International Health Board of the Rockefeller Foundation sent a team to investigate yellow fever in West Africa. After finding that the disease was both endemic and epidemic to an extent "greater than any official report would indicate," the team

recommended a long-term investigation and in 1925 the Rockefeller Foundation established the West African Yellow Fever Commission and began construction on an extensive laboratory near Lagos, Nigeria.[2] The commission's primary objective was to eradicate yellow fever from the West African coast through the mosquito control measures that had been successfully deployed in the Americas. It was therefore necessary to first confirm that yellow fever in West Africa was the same disease and that it was transmitted by the same mosquito vector, the *Aedes aegypti* mosquito. At the time it was thought that yellow fever was caused by a bacteria, but when the bacteriologists in Lagos failed to isolate the bacteria in question they began to doubt whether yellow fever in the Americas was in fact the same disease found in the African context. Then in 1927 researchers at the Pasteur Institute in Dakar and the Rockefeller team working in West Africa isolated a virus that was later verified as the causal agent of yellow fever on both sides of the Atlantic. This discovery figures prominently in the historical literature not only because it was the first flavivirus to be identified but because in 1931 the Asibi virus strain that the Rockefeller team isolated from a man named Asibi became the basis of what remains to this day one of our most effective and efficient vaccines—conferring what is now thought to be a life-time immunity to yellow fever in between 95 and 99 percent of those who receive the vaccine.[3]

The development of an effective preventive vaccine could not have come at a more fortuitous moment. In the early 1930s experts in Brazil found evidence that yellow fever was not simply an "urban" disease transmitted during epidemic outbreaks between human hosts by *Aedes aegypti* mosquitoes but that it also existed in an endemic form among primates. Sylvatic or "jungle" yellow fever, as the endemic form became known, had a more complex transmission cycle involving many different mosquito vectors and animal hosts and this was later found to be especially true in Africa. Serving as a permanent reservoir of disease and potential re-infection of

human populations and urban centers, endemic yellow fever meant that eradication would never be possible. Thus just as even the most ardent advocates of yellow fever eradication had to admit defeat, effective vaccines came on line to make complete eradication far less necessary. In a historiography of yellow fever that has almost exclusively focused on the Americas and to a lesser extent on narratives of eradication, the discovery of sylvatic yellow fever and the development of the vaccine tends to be the end of the story.[4] The mass vaccination campaigns that began in in Brazil in 1937 combined with targeted mosquito control measures put an end to the yellow fever epidemics that had once wreaked havoc across much of the "New World."[5] Yet in many ways, in the African context, this is just the beginning of the story. For while Rockefeller's West African Yellow Fever Commission did eventually pack its bags and leave Nigeria in 1934, the decision to abandon eradication in West Africa had been made before the discovery of sylvatic yellow fever in Brazil. In fact, the commission had planned to complete their work and leave Nigeria by the end of 1931. Citing inadequate sanitation as well as demographic and cultural factors, the commission report explained that, "the time was not yet ripe for the development of radical campaigns looking toward eradication of yellow fever in West Africa."[6]

As eradication appeared less and less feasible in West Africa, the commission began instead to study yellow fever immunity. Testing people for acquired yellow fever immunity sought to map the reach of yellow fever in Africa and around the world. With the expansion of commercial air travel, these "immunity surveys" were an essential means of preventing the global spread of yellow fever. Of special concern were the vast non-immune populations of Asia, where *Aedes aegypti* mosquitoes were found but, as immunity surveys confirmed, remained free from yellow fever. Air travel significantly raised the risk of infected travelers and mosquitoes

spreading the virus faster and further than ever before. Instituting precautionary measures required mapping the reach of endemic yellow fever.[7] After discovering that monkeys were susceptible to the disease and could be used in laboratory experiments, the West African Yellow Fever Commission developed what were called "protection tests." These tests involved injecting a previously unexposed monkey with both the virus and a human blood sample. A monkey that survived was "protected" by the immune bodies present in the person's blood, indicating that the individual had been exposed to yellow fever and lived in what was then deemed an endemic zone. If the monkey developed yellow fever, the blood did not appear to provide protective immunity indicating that the individual had not come into contact with the virus.[8] Performing protection tests on children as well as adults acted as a 'timestamp' providing evidence of when yellow fever had last visited a region. As each blood sample had to be tested on at least two monkeys in order to ensure accuracy, the initial immunity studies were expensive and time-consuming. The development of a mouse protection test in 1930 made more extensive examinations of immunity possible and in the early 1930s the Rockefeller Foundation agreed to devote substantial resources toward the delineation of endemic yellow fever across the globe.[9] Immunity surveys thus became the primary endeavor of the West African Yellow Fever Commission prior to its departure in 1934.[10]

Then in December 1935 a man died four days after admission in a Sudanese Hospital and all indications strongly suggested that he had been infected with yellow fever. This and other apparent clinical cases corroborated immunity surveys of Southern Sudan and Uganda which suggested yellow fever was not confined to West Africa as previously thought.[11] In cooperation with the British colonial administration, the Rockefeller Foundation's International Health Division created in 1936 a Yellow Fever Research Institute in Uganda (in the laboratory of the

former Human Trypanosomiasis Institute in Entebbe) in order to continue the immunity surveys throughout East and Central Africa and to investigate the epidemiology of yellow fever in this region of the continent. Needless to say Uganda, like Nigeria, became one of the most closely surveyed regions of the world, with blood samples tested for immunity in every region of the British Protectorate and in many cases this was done repeatedly. Between 1939 and 1946 a total of 15,834 blood samples were tested for immunity at the Institute's laboratory in Entebbe, Uganda and nearly 6,000 of them were from Uganda alone. In addition to identifying a number of previously unknown viruses including the now famous West Nile Virus, these immunity surveys confirmed the presence of yellow fever across East, West and Central Africa, allowing researchers to map what we now call the "African Yellow Fever Belt." According to the World Health Organization it is a region encompassing over 30 countries and affecting approximately 508 million people, spanning from the Sahel in the north to Angola in the South.[12] Moreover, because nearly half of the blood samples were taken from young children these immunity surveys indicated the recent presence of yellow fever in many regions of the continent.

From the evidence surrounding the protection tests and the debates over how to ensure the safety of air travel it is absolutely clear that the immunity surveys were a means of mapping endemic regions in order to shield vulnerable populations outside endemic zones. The historian Heather Bell, who has written one of the few published works on the history of yellow fever in Africa emphasizes this point in her chapter on yellow fever in the Sudan. Airports were made safe in part by forcing people living nearby to relocate and travelers to endemic regions received immunization. In the wake of an epidemic outbreak in the Nuba Mountains, quarantines prevented the spread of yellow fever to other parts of the Sudan and those entering or transporting goods through the quarantined region were given protective vaccines.[13] Thus it

appears that yellow fever research in Africa largely benefitted non-African populations. Yet the archival records of these immunity surveys suggest a more complicated picture. Even within highly endemic regions of the continent, regions where immunity surveys routinely identified individuals whose blood samples provided immunity to yellow fever, the vast majority of those tested did not appear to have immunity. Despite a few exceptions and at least one major caveat, preliminary analysis of the records indicate that the vast majority of people living within the endemic regions of the continent tested as non-immune.

Thus, for example, the West African Yellow Fever Commission's final report found that at least 50 percent of the people appeared to be protected from yellow fever in only 23 of the 149 the towns where blood samples were taken –in other words, in only 15 percent of the surveyed regions did at least half of those tested appear to have immunity to yellow fever. In 85 percent of the towns or 126 of the 149 surveyed at least 70 percent of the people did not appear to have immunity to yellow fever (and this figure notably excludes towns where 30 or more percent of the adults showed immunity but the children sampled did not). In many cases the percentage of people who had acquired immunity appears to have been far lower, as in Accra where only 8 percent showed immunity or Freetown where 22 percent of the adults but only 3 percent of the children had immunity or parts of the former Belgian Congo which also indicated immunity protection ranging from 0 to 19 percent in all but one case.[14] In East Africa where the very presence of yellow fever immunity came as a shock to many, the fact that the vast majority of the people had not acquired immunity to yellow fever is perhaps less noteworthy. Yet if this evidence is read as not only a map of endemic zones but also as an accounting of populations at risk for yellow fever infection the extent to which people within the "African Yellow Fever Belt" exhibited no immunity is of particular consequence. Taken in aggregate less than 9 percent of the

population in Uganda tested positive for acquired immunity to yellow fever, less than 12 percent of the Congo samples tested in East Africa, less than 10 percent of those from Zambia and less than 20 percent of the Sudanese. For Egypt, Eritrea, Somalia, Ethiopia, Kenya, Tanzania, present-day Malawi and Mozambique fewer than 5 percent appeared to be immune and in many of these territories the actual results indicated that less than 1 percent of the population may have been protected.[15]

The most important caveat that must be noted is that these protection tests were without question not sensitive enough to consider definitive.[16] More investigation is needed in order to establish how sensitive they may have been. What is more, the test itself erred on the side of caution when it came to reporting false positives. Thus the percentages cited above are certainly low and it is difficult to speculate about how much higher they might have been. Yet an expert on yellow fever in Africa, Thomas P. Monath, has cited more recent blood tests which indicate that the annual incidence of endemic yellow fever in Africa is approximately 1 percent, a figure suggesting that in the absence of large-scale epidemic outbreaks (or vaccination) acquired immunity and protection from yellow fever within endemic regions may have been quite low.[17] Certainly the immunity surveys conducted to map endemic yellow fever suggested that significant numbers of people living within the "African Yellow Fever Belt" may not have acquired immunity to the disease.

Preventive Vaccines and Vaccination in Africa

With yellow fever eradication off the table, the only viable recourse was to provide vaccines. In the French colonial territories vaccination began as early as June of 1934, using a vaccine developed by the Pasteur Institute in Dakar that became known as the "Dakar scratch

vaccine" because it was administered by simply scratching the vaccine under the skin. Beginning in 1940 this vaccine became the basis of widespread compulsory campaign in which 50 million doses were reportedly administered throughout the French colonial territories by 1960. In the early years of yellow fever vaccine development it was not known how long the immunity provided by the vaccine would last and so French authorities initially planned to administer the vaccine throughout their African colonial territories every 4 years. Yet, by 1950 they could no longer ignore reports of dangerous side-affects and in particular the development of encephalitis in children under the age of ten, resulting in numerous deaths. Although they stopped using the vaccine to immunize European children in 1951, it was not until 1960 that the same policy was applied to African children and production of the "Dakar scratch vaccine" continued surprisingly until 1982.[18]

Unfortunately the colonial subjects within the British African territories did not ultimately fare much better. Initially however the widespread use of vaccines in Anglophone Africa looked quite promising. In addition to continuing their immunity surveys, the Rockefeller Yellow Fever Institute in Uganda and in Nigeria after it reopened in 1944, focused a great deal on vaccination. Research questions that remained paramount included the safety of the Rockefeller vaccine, known as 17D, how long it took before the vaccine provided immunity and how long the immunity remained in effect. In Nigeria, researchers also tried in vain to develop a "scratch" version of 17D, as the scratch technique had many practical advantages.[19] Yet they did not adopt the French vaccine because even in the 1930s and 1940s there appear to have been questions about its safety and while 17D did initially encounter safety concerns, they were fairly rapidly addressed (and the more recent adverse cases that have been reported are exceptionally rare--1 in 200,000/250,000 for viscerotropic events resembling wild-type yellow fever and .3-.5

per 100,000 for neurotropic disease).[20] When I began this project I expected the refrigeration requirements of 17D to be the limiting factor, as the vaccine must be kept within a cold-chain to remain viable. And while ultimately the added costs thereby associated with 17D may have influenced the British decision to only provide yellow fever vaccines in the wake of an already emerging epidemic, this was not initially the case.

Despite the well-known refrigeration requirements of 17D, discussions about the development of a program to provide the vaccine on a widespread scale were already underway in the late 1930s as it was acknowledged that vaccination was a more cost-effective preventive measure than mosquito control.[21] Moreover, Rockefeller researchers involved in the immunity surveys recommended the implementation of both mosquito control and vaccination. When immunity surveys in 1942 indicated the presence of yellow fever in Eritrea, for instance, the experts at the Yellow Fever Research Institute in Uganda argued that, "In view of the fact that it will necessarily take considerable time to effectively control domestic mosquito breeding in Massawa the question of a mass vaccination of the population should be considered. This is a measure which could be carried out quickly and which would provide adequate protection during the time required to bring the mosquito vector under control."[22]

Nor were they simply being optimistic about the feasibility and efficacy of mass vaccination. Rather during the Second World War authorities met in Nairobi and Khartoum and decided to provide yellow fever vaccines "for all military personnel serving in Africa." The Rockefeller Foundation then provided the vaccine produced in its laboratories in New York as a contribution to the war effort and the Institute in Uganda "became a testing and distribution center for the whole of Africa east of Nigeria, and for the Middle East." The aim was to ensure that yellow fever did not "interfere with the war effort" or inadvertently spread to India and other

regions of the East. As part of preventing the global spread of yellow fever, "comprehensive programs of vaccination were undertaken in Eritrea and the coastal area of Kenya. Approximately 34,000 persons were inoculated in Eritrea by" the Institute's staff and after visiting the Institute for a week, a Dr. Philip oversaw the Kenyan vaccination of approximately 335,000 people. Thus although much of the over 3 million doses of vaccine distributed from Uganda between 1941 and 1945 were for military personnel, it was widely acknowledged that an unknown but significant segment of the civilian population received immunizations during the war –including police, hospital and railway workers and others involved in transportation. In Uganda the Asian population received vaccines, as did the Italian, Polish and other refugees and prisoners of war that were stationed in East Africa. Moreover, it was reported that despite this mass vaccination effort during the war, "no shipment of vaccine was ever lost, nor even sufficiently delayed in transit to render it unsuitable for use."[23]

What is more, an epidemic outbreak in western Uganda in 1941 led to what may have been the first mass vaccination campaign benefitting civilian populations in the British colonial territories. The epidemic occurred in Bwamba county where the Yellow Fever Research Institute established a field station in order to study the epidemiology of the disease on the edge of the Bwamba forest. The epidemic was discovered through repeated protection tests in which 48 people who had been non-immune according to tests performed in 1939, tested positive for yellow fever immunity in April and June of 1941. Thus although clinical cases were not forthcoming, this sharp increase in positive protection tests could only mean that an epidemic was underway and together with the colonial medical authorities, the Rockefeller staff immediately began a mass vaccination campaign. From June to August of 1941 they provided yellow fever vaccines to approximately 145,000 people in a fairly remote region of western

Uganda, bordering the present-day Democratic Republic of Congo.[24] In order to prevent the spread of the epidemic, the first to be inoculated were people residing in the surrounding territory of Toro. By the end of the campaign, vaccine had also been administered to the residents of Bwamba county who were at the center of the epidemic itself. The researchers at the Uganda Research Institute saw the provision of the vaccine as a major success and attributed the fact that the epidemic did not impact neighboring regions to their efforts.

In 1945, the Wellcome Institute in London and the South African Institute for Medical Research in Durban began production of 17D. The plan was for the Wellcome to supply the vaccine in Britain and the British West African territories and for the South African Institute to provide the vaccine for East and Central Africa. The archives held at the Rockefeller Archive Center suggest that in the immediate post-war period the aim was to provide vaccine on a massive scale as a preventive measure. In the end, this was not to be. Instead, the British decided on a policy of providing yellow fever vaccines only on a very limited scale and only in the wake of an already emerging epidemic, as in the case of the epidemic in Bwamba. Whether or not Bwamba was seen as a successful model, this then became the practice across most of the "African Yellow Fever Belt" in the post-independence period as newly independent countries began to shoulder the economic burden of public health expenditure. When the neo-liberal fiscal policies of structural adjustment later took an even greater toll on health spending, yellow fever vaccination coverage across much of the sub-continent was further undermined.

Conclusion

Thus although a relatively safe and highly effective vaccine has been available for over 75 years, the African people living with the greatest risk of yellow fever infection historically

had very little if any access to this life-saving preventive measure. It appears that the only vaccine made available to African people on a widespread basis had such dangerous side-effects that, although effective in preventing yellow fever outbreaks, it has not been in production for over three decades. The consequences are not difficult to discern. While yellow fever epidemics came to a standstill in the French colonial territories during the period coinciding with the compulsory vaccination campaign using the "Dakar scratch vaccine," outbreaks continued unabated in neighboring British colonial territories including notably present-day Nigeria, Ghana and the Gambia. Illustrating the public health risks facing non-immune populations living in endemic zones, one of the worst epidemics in recent times occurred in Ethiopia between 1960 and 1962 with over 100,000 cases and an estimated 30,000 deaths. Although yellow fever incidence in Africa is by some accounts significantly underreported (and according to some estimates is 10 to 500 times higher), there has been a pronounced upsurge in yellow fever since the early 1980s, which most observers attribute to a further breakdown in yellow fever vaccine coverage coinciding with the economic crisis and subsequent cuts in medical provision across the continent.[25] Nigeria again stands out with a reported 120,000 cases and 24,000 deaths.[26] And while most epidemics have been concentrated in West Africa over the past twenty years, there have also been outbreaks in Kenya and southern Sudan and overall incidence has been steadily on the rise.[27]

The World Health Organization estimates that over 90 percent of yellow fever cases occur in Africa. This was notably not always the case. From 1950 to 1959 an average of 36 cases were reported annually from Africa as compared to 292 annual cases in the Americas, during the same time period. Putting aside the problem of underreporting, this suggests that the burden of disease has shifted significantly from a time when yellow fever had an impact in the Americas

that was comparable if not greater than in Africa to one in which yellow fever has become largely an "African disease." Moreover, since mid-century the Americas have been almost entirely free from epidemic outbreaks with yellow fever incidence confined to the "jungle" or sylvatic transmission cycles occurring predominantly among people working in forested regions. The last "urban" outbreak in the Americas reportedly occurred in Brazil in 1942.[28] Due to mosquito control programs, which were often tied to or contingent on adequate water supplies, and mass vaccination campaigns, yellow fever incidence was significantly reduced in the Americas. Despite their proven efficacy these same measures have not been implemented in Africa. When we think then of Africa's high burden of disease, at least in the case of yellow fever, we must keep in mind that this was neither natural nor inevitable. Rather it is the result of decisions denying African people access to preventive medical care.

Finally, and on a more positive note, in the first year of the new millennia the Global Alliance for Vaccines and Immunization or GAVI began to fund a program to include the yellow fever vaccine in the Expanded Programme of Immunization (EPI) for children in Africa, as had been the official (WHO) recommendation since 1988. After five years, the very low vaccine coverage in Africa began improving with 22 of the 33 countries within the yellow fever belt adopting a policy for yellow fever immunization and three reaching the coverage levels required to avoid epidemic outbreaks.[29] A recent analysis of vaccine coverage in Ghana, for instance, found that 85 percent of the children within the survey received the yellow fever vaccine.[30] Yet the significant lapse in the provision of yellow fever vaccines in Africa left the bulk of the population in many endemic regions without protection and simply integrating the vaccine into routine childhood vaccination programs would not prevent epidemics for years to come. As a result, a Yellow Fever Initiative began in 2005 as a partnership between WHO, UNICEF, GAVI

and the respective ministries of health in order to launch a "catch-up immunization" campaign across West Africa. Between 2006 and 2012 approximately 69 million people in 13 countries received the yellow fever vaccine, and in 2013 GAVI devoted additional funds for the continuation of the initiative and vaccination programs begun in Nigeria and Ethiopia –although the Ethiopian campaign is an emergency mass-vaccination following six confirmed cases of yellow fever in May of 2013.[31] If these efforts continue it is possible that, as in the Americas, major yellow fever epidemics in Africa may become a thing of the past, perhaps even without mosquito control and expanded provision of water and sanitation. To sustain the promise of this initiative requires funding for ongoing childhood immunization in Africa. The alternative is, however, far more costly both in terms of the lives unnecessarily lost to yellow fever and in the far higher cost of emergency immunization. According to one analysis, providing immunization in the wake of an already emerging epidemic is not only far less effective but costs over $7 versus the 65 cents per vaccine it is estimated to cost (in 1991 currency) to incorporate yellow fever into routine childhood immunization programs.[32] Perhaps in the not too distant future Africa will no longer bear an unequal burden of this one highly fatal but easily preventable disease.

[1] This is an abbreviated version of a paper originally presented at the 2014 World History Association Conference, University of Costa Rica, July 16-18, 2014.
[2] "No. 7543, Report of the Yellow Fever Commission to West Coast of Africa, July 19 to October 30, 1920," March 18, 1921, p. 25, Folder 2650, Box 214, Series 3, RG 5, International Health Board/Division records, FA115, Rockefeller Foundation records (RF), Rockefeller Archive Center (RAC).
[3] For the Pasteur work see Myron Echenberg, "'For Their Own Good:' The Pasteur Institute of Dakar and the Quest for an Anti-Yellow Fever Vaccine in French Colonial Africa, 1924-1960," in *Les Conquêtes De La Médecine Moderne En Afrique*, ed. Jean-Paul Bado, Tropiques (Paris: Karthala, 2006), 53–69.The vaccine is also considered highly safe although the initial use of human serum led to serious side-effects including and outbreak of jaundice and Hepatitis B and more recent side-effects have also emerged and are under investigation. For the recent determination that the vaccine provides life-time immunity see null Who, "Vaccines and Vaccination against Yellow Fever: WHO Position Paper, June 2013-Recommendations," *Vaccine*, May 20, 2014, doi:10.1016/j.vaccine.2014.05.040.

[4] Nancy Stepan, *Eradication: Ridding the World of Diseases Forever?* (Ithaca, NY: Cornell University Press, 2011); John Farley, *To Cast Out Disease: A History of the International Health Division of the Rockefeller Foundation (1913-1951)* (Oxford ; New York: Oxford University Press, 2004); Marcos Cueto, "Sanitation from above: Yellow Fever and Foreign Intervention in Peru, 1919-1922," *The Hispanic American Historical Review* 72, no. 1 (February 1, 1992): 1–22, doi:10.2307/2515945.
[5] Farley, *To Cast out Disease*, 172.
[6] "Seventh Annual Report, West African Yellow Fever Commission 1931," p. 2, RF 5 Series 3 Box 215 Folder 2662, RAC.
[7] Heather Bell, *Frontiers of Medicine in the Anglo-Egyptian Sudan, 1899-1940* (Oxford University Press, 1999), 168–169.
[8] Henry Beeuwkes, J. H. Bauer, and A. F. Mahaffy, "Yellow Fever Endemicity in West Africa, with Special Reference to Protection Tests," *The American Journal of Tropical Medicine and Hygiene* 10, no. 5 (1930): 305–33.
[9] Bell, *Frontiers of Medicine in the Anglo-Egyptian Sudan, 1899-1940*, 168–170.
[10] "Seventh Annual Report, West African Yellow Fever Commission 1931"; "Eighth Annual Report, West African Yellow Fever Commission 1932," 1932, RF 5 Series 3 Box 215 Folder 2663, RAC.
[11] "Annual Report for 1936, Paris Office-International Health Division, Section 4-Uganda Yellow Fever Research Institute," p. 3–4, RF 5 Series 3 Box 241 Folder 2905, RAC.
[12] John-Paul Mutebi and Alan D. T. Barrett, "The Epidemiology of Yellow Fever in Africa," *Microbes and Infection* 4, no. 14 (November 2002): 1459–68.
[13] Bell, *Frontiers of Medicine in the Anglo-Egyptian Sudan*, 175–176 and 185-194.
[14] "Eighth Annual Report, West African Yellow Fever Commission 1932," p. 1–10, RF 5 Series 3 Box 215 Folder 2663, RAC.
[15] "Yellow Fever Research Institute, Entebbe, Uganda, Report of Studies, 1939-1946," 1946 1939, 6, RF 5 Series 3 Box 211 Folder 2608, RAC.
[16] I thank my colleague Dr. Ken Stedman for bringing this to my attention.
[17] T. P. Monath, "Yellow Fever as an Endemic/Epidemic Disease and Priorities for Vaccination," *Bulletin De La Société De Pathologie Exotique (1990)* 99, no. 5 (December 2006): 345.
[18] Echenberg, "'For Their Own Good:' The Pasteur Institute of Dakar and the Quest for an Anti-Yellow Fever Vaccine in French Colonial Africa, 1924-1960"; Greer Williams, *Virus Hunters.* (New York: Knopf, 1959).
[19] "West Africa, Yellow Fever Research Institute Annual Report 1944," 1944, RF 5 Series 3 Box 215 Folder 2665, RAC.
[20] Staples J and Monath TP, "Yellow Fever: 100 Years of Discovery," *JAMA* 300, no. 8 (August 27, 2008): 960–62, doi:10.1001/jama.300.8.960; Galbraith and Barrett, "Yellow Fever;" Williams, *Virus Hunters*; J. Gordon Frierson, "The Yellow Fever Vaccine: A History," *The Yale Journal of Biology and Medicine* 83, no. 2 (June 2010): 77–85.
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[22] "Yellow Fever Research Institute, Entebbe, Uganda, Semi-Annual Report, January to June, 1942," 1942, Appendix II, pp. 3-4, RF 5 Series 3 Box 211 Folder 2600, RAC.
[23] "Yellow Fever Research Institute, Entebbe, Uganda, Report of Studies, 1939-1946," 43–46.
[24] "Yellow Fever Research Institute, Entebbe, Uganda, Report of Studies, 1939-1946."
[25] Mutebi and Barrett, "The Epidemiology of Yellow Fever in Africa."
[26] Staples J and Monath TP, "Yellow Fever."
[27] Monath, "Yellow Fever as an Endemic/Epidemic Disease and Priorities for Vaccination;" Mutebi and Barrett, "The Epidemiology of Yellow Fever in Africa."
[28] Mutebi and Barrett, "The Epidemiology of Yellow Fever in Africa," 1464.
[29] Monath, "Yellow Fever as an Endemic/Epidemic Disease and Priorities for Vaccination," 347.
[30] Lu Gram et al., "Socio-Economic Determinants and Inequities in Coverage and Timeliness of Early Childhood Immunisation in Rural Ghana," *Tropical Medicine & International Health: TM & IH* 19, no. 7 (July 2014): 802–11, doi:10.1111/tmi.12324.
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[32] T. P. Monath and A. Nasidi, "Should Yellow Fever Vaccine Be Included in the Expanded Program of Immunization in Africa? A Cost-Effectiveness Analysis for Nigeria," *The American Journal of Tropical Medicine and Hygiene* 48, no. 2 (February 1993): 274–99.