

# THE EXODUS SYNDemic: THE EPIDEMIOLOGY OF THE TENTH PLAGUE

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## INTRODUCTION

The Bible tells of ten plagues that preceded the Exodus.<sup>1</sup> While the ten plagues are presented in the Bible as miraculous, upon examination it is seen that the sequence of the plagues can be understood as following an epidemiological pattern, revealing what may be seen as the mechanism behind the miracle. In 1996, one of the present authors and a colleague wrote an article exploring the nature of the ten plagues from an epidemiological perspective (“Marr/Malloy”).<sup>2</sup> The article showed how the plagues progressively degraded the Egyptians’ water and food supplies, limited their modes of transportation, compromised their health, and in sum made them more susceptible to the afflictions that eventually killed their first-born in the tenth plague. Marr/Malloy characterized the tenth plague as a “mysterious affliction” on the premise that both the disease and the deaths occurred suddenly and at more or less the same time, likely resulting from a lethal mix of food and airborne mycotoxins. But the Bible allows for the inference that the deaths in the tenth plague were caused by a combination of epidemics brought on by earlier plagues, in what is known today as a “syndemic” (the synergistic effect of multiple epidemic events). Viewed from this perspective, the epidemiological sequence and role of the first nine plagues may have been even more dramatic than was previously thought.<sup>3</sup>

Moreover, if the deaths in the tenth plague resulted from infections inflicted by swarms of insects in the fourth plague (*arov*) and diseases first inflicted on livestock in the fifth plague (*dever*) and then transmitted to humans, it bears

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noting that the Bible is reporting an epidemiological sequence unknown to medical science until a few centuries ago.

#### THE TENTH PLAGUE

The tenth plague provides a context for the epidemiological analysis. God's plan from the very beginning was to punish the Egyptians for their mistreatment of the Israelites by killing their first-born (Ex. 4:22-3). Otherwise, as God informed Pharaoh through Moses, He could have killed the first-born with a single plague, and done so immediately (Ex. 9:15).

The Bible allows for the possibility that the tenth plague was a syndemic resulting from earlier plagues. It is silent as to whether the Egyptians and animals that died in the tenth plague on a single night were also first infected on that night. In Exodus 9:14, God told Moses after the sixth plague that He was about to afflict the Egyptians with *all My plagues* [*magefot*], using the plural form of the Hebrew *magefah*, here meaning disease. In his commentary on Exodus 7:27, Rashi explains that a *magefah* typically does not involve death. However, when it comes to interpreting *magefot* in 9:14, he concludes that it refers to the deaths in the tenth plague. Moreover, God later characterized the plagues in general as multiple diseases (Ex. 15:26; Deut. 7:15; 28:60-61).<sup>4</sup> Since the only preceding plague that was manifestly a disease was the fifth plague, and only animals were the proximate victims of that plague, the reference to multiple diseases seems best understood as alluding mainly to the tenth plague. In addition, it is inferable that life-threatening diseases had already taken hold among the Egyptians when Pharaoh pled for Moses to entreat God to *remove from me just this death* (Ex. 10:17).<sup>5</sup>

#### DURATION OF THE PLAGUES

An estimate of the plagues' duration will help identify the diseases most likely to have produced the deaths in the last plague, because the period between initial infection and death varies by disease.<sup>6</sup> The plagues ended on the night before the Israelites departed Egypt, which was on the 15<sup>th</sup> day of the Jewish calendar month of Nissan (Ex. 12:51), generally corresponding to April of our modern-day solar calendar. However, when the plagues began is not as clear. But a number of biblical clues point to August or September. Before the first plague, God told Moses and Aaron to approach Pharaoh

when he went to the bank of the Nile (Ex. 7:15). Ibn Ezra explains that Pharaoh's reason for going to the Nile was to check on the height of its yearly inundation, meaning in his view the Hebrew month of Tammuz or Av (roughly July or August).<sup>7</sup> The Bible hints at the inundation again when Aaron caused *all [of Egypt's] bodies of water* (Ex. 7:22) to turn to blood, even the water on the trees and stones, as Cassuto translates it.<sup>8</sup> Indeed, this seems to be a fairly accurate reflection of the Nile floodplain, which featured irrigation canals, ponds and other bodies of water, as well as trees and rocky terrain.<sup>9</sup> The Nile normally reaches full inundation by August or September.<sup>10</sup> Since the inundation is said to reach "bankfull" in northern (Lower) Egypt by September, we can infer that the first plague occurred around the beginning of September. Thus, the plagues appeared to have played out over 7-8 months (early September to mid-April).

#### EPIDEMIOLOGICAL ASPECTS OF THE FIRST NINE PLAGUES

**Nile Waters Turned to Blood.** Regardless of whether the Nile's water was turned into actual blood or a blood-like substance,<sup>11</sup> its contamination would have posed a heightened health risk for quite some time.<sup>12</sup> The Bible tells us that seven days passed after the plague itself was first inflicted, leaving room to conclude that the unhealthy after-effects of the contamination and dead fish continued beyond the duration of the plague.

The Nile contamination may also have had a more direct epidemiological consequence. This river hosted a fairly long list of parasitic agents that could have infected the ancient Egyptians. For instance, it is possible that the first plague exposed the large Egyptian population that inhabited the Nile Valley to the parasitic blood fluke schistosomiasis (*Schistosoma mansoni* and *S. haematobium*), which is still endemic in the Nile River.<sup>13</sup> Endemic schistosomiasis in and of itself would not have killed the Egyptians in the timeframe we posit for the plagues.<sup>14</sup> However, schistosomiasis can cause inflammation that predisposes victims to septic salmonellosis,<sup>15</sup> a much more serious disease to which the Egyptians could have been exposed by their livestock as a consequence of the fifth plague. Once salmonella bacteria gain access to a person's blood stream, fatality is very high; the myriad portals of entries into the blood stream offered by a concurrent schistosomal infestation would have produced fatal septicemia in its victims.<sup>16</sup>

**Frogs.** As Marr/Malloy noted, the death of the frog population had at least two epidemiological consequences. First, millions of decaying frog carcasses created a new breeding ground for deadly bacteria (like Salmonella) throughout Egypt. Second, their death removed an important check on insect populations that could transmit numerous diseases. Most notably, the death of the frogs and fish that kept snail populations in check allowed a massive increase in the snails -- the intermediate hosts for schistosomiasis. Massive infestation with schistosomal flukes would certainly have increased the parasitic burden and shortened the time between initial infection and end stage disease from years to months.

**Lice.** This plague is described as attacking both animals and humans. Most rabbinic commentators (and the Septuagint) translate it as lice.<sup>17</sup> It seems unlikely that lice contributed to the human deaths months later in the tenth plague, since the main risk is typhus caused by lice-borne bacteria, and death from typhus occurs within days or weeks.<sup>18</sup> However, severe louse infestations in cattle and other livestock can produce serious secondary infections and nutritional deficiencies that would have compromised the animals as a source of both transportation and food.

**Flying Insect Swarms.** The Talmudic sage Rabbi Nechemia opined that the Hebrew word for the fourth plague, *arov*, signifies swarms of mosquitoes, gnats and wasps.<sup>19</sup> We now know that flying insects are vectors that could have inflicted the Egyptians with an array of infectious diseases.<sup>20</sup> The two diseases deserving most serious consideration are malaria and leishmaniasis.

Malaria, endemic to ancient Egypt, is a serious and often fatal disease.<sup>21</sup> It is caused by various species of *Plasmodium*, a protozoan parasite transmitted through the bite of an infected female *Anopheles* mosquito. In the human body, parasites multiply in the liver, and then infect red blood cells (RBCs), causing their destruction. Symptoms (fever, chills, rigor) appear a few weeks after the bite, although they may occur as much as a year later, depending on the species of malaria parasite. Fatalities from *P. falciparum* malaria are due to massive RBC destruction and sludging and occlusion of blood vessels.

Leishmaniasis,<sup>22</sup> another parasitic disease endemic to ancient Egypt, is transmitted by the bite of infected sand flies. The forms include visceral leishmaniasis (also known as kala azar), which destroys the lymphopoietic organs (liver, spleen and bone marrow). The incubation period between bite

and onset of a cutaneous lesion is a few weeks for both, but visceral leishmaniasis may progress for months leading to severe anemia, renal damage, mucosal hemorrhage and death. If one survives the disease, a condition known as “post-kala-azar dermal leishmaniasis” - whose symptoms include multiple raised warty skin lesions that may have appeared in the sixth plague (boils) - may occur.

**Animal Disease.** The fifth plague afflicted the Egyptians’ livestock – the Bible specifically mentions horses, donkeys, camels, cattle and sheep (Ex. 9:2) - with one or more potentially lethal infections primarily limited to animals. Many of these animals died (Ex. 9:6).<sup>23</sup> We focus here on three animal diseases known to have occurred in ancient Egypt that are transmittable to humans: anthrax, leptospirosis, and brucellosis.<sup>24</sup>

Anthrax is a spore-forming bacterial disease found naturally in soil.<sup>25</sup> Contact with soil, in farming for example, can infect humans through a cut or scrape in the skin. However, anthrax is more commonly transmitted by contact with infected animal products -- fur, skin, hide, wool, hair, milk and milk products.<sup>26</sup> Infection usually develops within one to seven days and produces a painful, black ulcer. Animals and humans may also become infected by inhaling air-borne spores or ingesting plants, water or tainted meat. Inhalational anthrax -- the deadliest form of this disease -- may take anywhere from a few weeks to a few months to develop. Anthrax can also be transmitted by flies.

Leptospirosis, a water-borne bacterial disease, affects both humans and animals. Most mammals (especially rodents) and secondarily infected domestic animals carry the bacterium in their urine. The free-living bacteria survive in water for weeks to months and enter the body through breaks in the skin or directly through mucous membranes. The incubation period between exposure and illness is within a few days to a month. Symptoms include a characteristic skin rash, alternating high fever, signs of meningitis and progressive liver and kidney disease and death.

Brucellosis (undulant fever)<sup>27</sup> is a bacterial disease acquired from food-producing animals -- sheep, cattle, goats, and pigs. Infection in sheep and goats is highly contagious and may be transmitted to other animals and humans. Infected animals kept in close proximity to housing may produce heavy contamination of streets, market places and within houses. The most

common mode of transmission to humans is ingestion of dairy products – milk, cheese, and other milk products – although contact with contaminated objects may also transmit brucellosis. Symptoms including recurrent fevers, muscle and joint pains, and progressive anemia may develop over a period of weeks to months. A variety of skin lesions have been reported in patients.<sup>28</sup> Death from brucellosis is rare but may occur, and the disease itself is debilitating.

**Boils and Blisters.** Boils and blisters are common manifestations of many infectious diseases. The boils and blisters of the sixth plague, which attacked both humans and animals, may not have been a separate disease but rather the result of fly bites or penetrating schistosomal larvae.<sup>29</sup> Pharaoh’s magicians were unable to stand because of the boils, which may indicate an inflammation of the legs and feet, common to schistosomiasis. Blisters are not mentioned as one of their symptoms, implying that the blisters were either short-lived or not widespread.

The sixth plague appears to have taken a dramatic and ominous turn toward the lethal tenth plague. It was the first of the plagues launched by Moses himself (Ex. 9:10). It was also the first time that God saw the need to *harden the heart of Pharaoh* (Ex. 9:12) This may tell us that the sixth plague was the first one to cause Pharaoh palpable pain and trepidation. Perhaps this explains why some commentators say God “hardened” his heart to prevent him from relenting out of pain rather than remorse.<sup>30</sup>

**Severe Hailstorms.** Marr/Malloy characterizes this plague as “the antepenultimate assault on the Egyptians’ existing food supply, which would be further tested by the eighth plague” (Ex. 9:25, 31). God forewarned the Egyptians, before the storms struck, that they could save their livestock by bringing them inside their houses to protect them from the savage weather. We are told that Egyptians who *feared the word of the Lord* (Ex. 9:20) did so, which perhaps is better understood as a fear of further suffering rather than an indication of contrition. What is important for our purposes is that, by bringing livestock into their homes, the Egyptians increased their risk of contracting disease through contact with their diseased animals’ bodily fluids, urine, excrement, and contaminated fur, wool and hair.

**Locusts.** As Marr/Malloy observe, the damage inflicted by the locusts on the vegetation and fruits that survived the hailstorms (Ex. 10:15) further de-

graded the Egyptian food and medicinal supplies.

**Darkness.** An epidemiological cause of the ninth plague is hard to discern. However, if the *Torah Temimah*, the 20<sup>th</sup> century commentator Rabbi Baruch Halevi Epstein, is correct in suspecting<sup>31</sup> that the Egyptians could not see each other (Ex. 10:23) because of an eye disease, this would support an epidemiological interpretation that at least one of the epidemic diseases caused blindness.<sup>32</sup> Transient blindness may occur during many acute infections.

#### CONCLUSION

The biblical narrative is consistent with an epidemiological chain reaction. Most importantly, the human deaths in the tenth plague may have resulted from insect-borne diseases borne by the fourth plague insect swarms and from fifth plague livestock diseases that were transmitted to humans. Although a natural explanation for the death of all first-born Egyptian humans and livestock remains elusive, perhaps a cogent one will emerge in time. Even if this particular aspect of the tenth plague remains in the realm of the miraculous, we have seen that the sequence of the plagues is structured as a series of epidemics, leading up to the deadly syndemic of the final plague. While fundamentally miraculous, the plagues, including the tenth plague, were based on a disease model.

#### NOTES

1. The historicity of the Exodus is debated among scholars (see L. T. Geraty, "Exodus Dates and Theories," *Israel's Exodus in Transdisciplinary Perspective: Text, Archeology, Culture and Geoscience* (T.E. Levy, T. Schneider, W.H.C. Propp, eds.) (New York: Springer, 2015) pp. 55-64).
2. J. S. Marr and C. D. Malloy, "An Epidemiologic Analysis of the Ten Plagues of Egypt," *Cadaceus* 12:1 (1996) pp. 7-24.
3. This epidemiological interpretation of the ten plagues is intended in the spirit of rabbinic opinion that permits, and perhaps even invites, inquiry into natural explanations of the plagues. The Rambam, himself a physician, considered "almost all miracles [to be] miraculous as to the time and place of occurrence while the event itself [the plague] is part of the order of nature" (B. Wein, *Pesach and Locusts* (<<http://www.rabbiwein.com/blog/post-1465.html>>)). However, nothing in this article is intended to question the occurrence of miracles in connection with the ten plagues or with the Exodus itself.
4. See, e.g., Ohr HaChaim (Ex. 15:26), noting that various diseases were inflicted on the Egyptians.

5. Unless otherwise stated, all biblical translations in this article are from The Judaica Press, which may be found at <[http://www.chabad.org/library/bible\\_cdo/aid/63255/jewish/The-Bible-with-Rashi.htm](http://www.chabad.org/library/bible_cdo/aid/63255/jewish/The-Bible-with-Rashi.htm)>.
6. It must be borne in mind that almost any infection, however rare or common its lethality might be, may expose humans and animals to death by sepsis or other causes, natural or divine.
7. For additional rabbinic commentary to this effect, see Y. Culi, *The Passover Haggadah* (A. Kaplan, tr.) (New York: Moznaim, 1989) pp. 71-75.
8. U. Cassuto, *A Commentary on the Book of Exodus* (I. Abrahams, tr.) (Jerusalem: Magnes, 1952) p. 99. Cassuto thus disagrees with the many rabbinic commentators who understand this as a reference to water in wooden and stone vessels. He explains that vessels of wood and stone were uncommon in Egypt at the time of the Exodus.
9. 8 *Encyclopedia Britannica* (Chicago: Encyclopedia Britannica, Inc., 1957) pp. 34-35; see, also, K. W. Butzer and L. G. Freeman, *Early Hydraulic Civilization in Egypt* (Chicago: Univ. of Chicago, 1976) pp. 16, 20 (accessible at <[oi.uchicago.edu/pdf/early\\_hydraulic.pdf](http://oi.uchicago.edu/pdf/early_hydraulic.pdf)>).
10. Butzer and Freeman write that under normal conditions the Nile inundation reaches bankfull stage in the southern Nile by mid-August and in the northern Nile (where the Israelites lived) 4-6 weeks later, which puts its highest level around the beginning of October. The southern banks and basins are dry by early October and those in the north by sometime in November. *Ibid*, pp. 17-18.
11. For an overview of various rabbinic opinions, see H. Babich, "Blood, Frogs and Lice," *Pesach-to-Go 5769* (R. Shur, ed.) (New York: 2009) p. 6. Babich credits Z. Sorotzkin, *Insights in the Torah*, Vol. 2 (*Shemos*) (Brooklyn: Mesorah, 1993). If the plague involved a blood-like substance, Marr/Malloy would attribute the water's appearance, and the fish deaths, to a toxic algal bloom (red tide).
12. The Nile was the center of Egyptian life, and the Egyptian population was heavily concentrated in the Nile valley. One historian who studies epidemics observed: "Density of human settlement has special importance for the spread of many diseases, especially airborne ones, whether bacterial ... or viral ... ." (J. N. Hays, "Historians and Epidemics: Simple Questions, Complex Answers," *Plague and the End of Antiquity: The Pandemic of 541-750* (L. K. Little, ed.) (Cambridge: Cambridge U. Press, 2007) p. 46.
13. J. F. Nunn, *Ancient Egyptian Medicine* (Norman: Univ. of Oklahoma, 1996) pp. 64-77. "Epidemic" refers to the usual number of cases of a condition. A surge above the usual number is called an "epidemic". A continuous high level, or a sustained epidemic, is referred to as "hyperendemic".
14. Another water-borne parasite, drancunculiasis (*Drancunculus medinensis*, known as Guinea worm disease) was a common affliction in Egypt. Fossilized remains of the foot long worms have been found in Egyptian mummies. It is not fatal per se.
15. Salmonellosis is a bacterial infection transmitted to humans by consumption of contaminated food of animal origin (mainly eggs, meat, poultry and milk), vegetables contaminated by manure, contaminated water, or contact with infected domestic or wild animals or their excrement. With nearly 2,500 Salmonella "species" (serovars), it is found in almost every warm and cold-blooded animal.
16. J. R. Lambertucci, et al., "Schistosomiasis and Associated Infections," in 93 *Memórias do Instituto Oswaldo Cruz* (1998) (<<http://dx.doi.org/10.1590/S0074-02761998000700019>>).



17. Some, including Rashbam (Ex. 8:12) suggest it may mean a flea.
18. Sucking lice (*pediculus*) can infect man, domestic animals and wild animals. Lice infections have been found on mummies from ancient Egypt. The human body louse (*Pediculus humanis humanis*) can transmit *Rickettsia prowasekii*, a bacterium that causes epidemic typhus. Epidemic typhus has occurred when populations have been disrupted or concentrated by famine or floods and the attendant insanitary conditions (14 *Encyclopedia Britannica*, pp. 436-437). It bears note that although Ibn Ezra believes the first three plagues attacked the Israelites as well (Ex. 7:24), it is a minority view. Even if he is correct – and he does draw from a plain reading of the text – it may still be the case that by natural means or divine intervention the Israelites did not become ill as a result of their lice infestation.
19. *Exodus Rabbah* 11:3. Similarly, the Septuagint translated *arov* as “dog flies”, commonly known today as stable flies.
20. The role insects and rodents play in transmitting infectious diseases was first discovered in 1894 by Alexandre Yersin and Kitasato Shibasaburō. Yersin’s work on the causal agent of bubonic plague was soon supplemented by others, confirming a complex epidemiological chain of events between the germ on the one hand, and the relationship among its nidality, reservoir, vector, and various modes of transmission on the other. The reservoirs were discovered to be various peridomestic rodents -- rats, gerbils, squirrels and marmots. Transmission occurred through intimate contact with rodents, by the bite of their resident fleas, and in some instances directly from human to human. Before these discoveries, diseases were attributed to divine wrath or “the elements.” So, for example, the Talmudic sage Shemuel (2<sup>nd</sup>-3<sup>rd</sup> century CE), himself a physician, believed that all sickness and death was due to the wind (Babylonian Talmud, Bava Metziyah 107b). Hippocrates (5<sup>th</sup>-4<sup>th</sup> century BCE) thought that infections had something to do with “humours” (E. W. Goodall, *On Infectious Diseases and Epidemiology in the Hippocratic Collection* (Proceedings of the Royal Society of Medicine) (December 6, 1933) p. 534 (accessible at <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2204767/pdf/procrsmed00693-0007.pdf> ).
21. Perhaps the best-known evidence of malaria deaths in ancient Egypt surfaced from a 2010 anthropological, radiological, and genetic study that was performed on sixteen royal mummies thought to be associated with Tutankhamen (Z. Hawass, et al., “Ancestry and Pathology in King Tutankhamen’s Family,” in *Journal of the American Medical Association* 303 (2010) pp. 638–647). Four mummies were found to have traces of malaria, and Tutankhamen’s skin showed possible evidence of a boil, “plague spot”, or inflamed insect bite.
22. Much of the information in this article on leishmaniasis is taken from World Health Organization, *Control of the Leishmaniases: Report of a meeting of the WHO Expert Committee on the Control of Leishmaniases, Geneva, 22–26 March 2010* (Geneva, 2010) (accessible at <[http://whqlibdoc.who.int/trs/WHO\\_TRS\\_949\\_eng.pdf](http://whqlibdoc.who.int/trs/WHO_TRS_949_eng.pdf)>).
23. Exodus 9:6 reports that “all the livestock of the Egyptians died.” However, a number of commentators, noting that livestock were also attacked in the seventh and tenth plagues, interpret this phrase as meaning that only Egyptian livestock died (see, e.g., Chizkuni on this verse).
24. Livestock-to-human transmission is relevant because the vast majority of Egyptians were farmers (B. Brier and H. Hobbs, *Ancient Egypt: Everyday Life in the Land of the Nile* (New York: Greenwood, 2009) p. 96). Many Egyptians owned dogs as well as some farm animals (K. Szpakowska, *Daily Life in Ancient Egypt: Recreating Lahun* (Massachusetts: Blackwell, 2008) p. 19).

25. Halioua and Ziskind consider anthrax to be the most likely candidate for the disease inflicted by the fifth plague. See B. Halioua and B. Ziskind, *Medicine in the Days of the Pharaohs* (Cambridge: Belknap, 2005) p. 201.
26. The Egyptians consumed more milk than in many other cultures (Brier and Hobbs, *Everyday Life*, p. 125), and milk was highly valued as a component of medical remedies (Nunn, *Ancient Egyptian Medicine*, pp. 14-16). In addition, animal excrement and other byproducts were used in preparing drugs (*Ibid*, pp. 38, 149, 201).
27. Ancient Egyptian bones dating to around 750 BCE showed evidence of lesions that are common complications of brucellosis (M. N. Seleem, et al., "Brucellosis: A Re-emerging Zoonosis," in *Veterinary Microbiology* 140 (2010) pp. 392-398).
28. World Health Organization, *Brucellosis in Humans and Animals* (Geneva, 2006) (accessible at <<http://www.who.int/csr/resources/publications/Brucellosis.pdf>>).
29. If this plague involved the appearance of symptoms but did not inflict new diseases, this could help explain why it is the only one not mentioned in either Ps. 78:43-51 or 105:27-36.
30. See, e.g., Seforno (Ex. 7:3), expressing the view that God would not have prevented Pharaoh from exercising his free will and genuinely repenting.
31. Rabbi Epstein writes: "Were I not reluctant to suggest something very new, I would say that the incident of darkness was not in the air, but in the people's eyes. That is, they had something obscuring their pupils. Our sages said that the thing that obscured their vision could be touched with the hand and was as thick as a *dinar*. This explains everything." (*Torah Temimah* on Ex. 10:21).
32. For example, trachoma ("Egyptian ophthalmia") is a bacterial infection (*Chlamydia trachomatis*) transmitted person to person by houseflies, which have always abounded in Egypt. It damages the conjunctiva and cornea. It may have infected Egyptians.



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