

“Epidemic Louse-Borne Typhus, and biological and socio-economic factors: a review of
disease events during the Irish potato famine and recent history”

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Abstract

Epidemic Louse-Borne Typhus (EL-BT) poses an epidemiological threat to global public health. *Rickettsia prowazekii* (*R. prowazekii*) is the etiologic agent of EL-BT. This thesis inductively identifies causative factors of EL-BT events, and does so using an array of historical outbreaks over the last century and a half. Four cases were historically reviewed: the 19th-century Irish potato famine and EL-BT epidemic, and three 20th-century EL-BT events. The thesis uses these past and contemporary real-life accounts of *R. prowazekii* events, and explains how both biological and socio-economic factors uniquely birth and perpetuate EL-BT outbreaks. Both historically and contemporarily, the results show an empirical relationship between socio-economic and biological factors and EL-BT disease events. The causality of EL-BT may be attributed to poverty (a socio-economic factor), homelessness (a socio-economic factor), unsanitary conditions (both a socio-economic and biological factor), famine (a biological factor), and body lice infestation (a biological factor). Public health practitioners and policymakers are right to focus programs and policies on not only biological, but also expressly socio-economic, factors in order to address EL-BT. U.S. policymaking efforts, including recent administration budget requests, signal an opportunity to intentionally address both biological and socioeconomic causes of not only EL-BT, but also other disease events.

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Chapter 1 - Research Framework and Literature Review

Introduction

Throughout history, there have been several pivotal moments in global disease epidemiology. Historical epidemics commonly originated from a zoonotic pathogen—a microorganism of animal origin that causes diseases transmissible to humans. However, in the 1840s, a pathogen of plant origin triggered a cascade of political, medical, religious, and ethical dilemmas in several countries that helped shape modern epidemiology. *Phytophthora infestans* (*P. infestans*), a fungus that causes potato blight, devastated a vital food source in Ireland between 1845 and 1850. This commodity loss led to an event named "The Irish Potato Famine." Widespread starvation, massive loss of life, a subsequent outbreak of Epidemic Louse-Borne Typhus (EL-BT), and a massive emigration from Ireland occurred. Emigration to the United States carried economic, social, and political consequences. These events have shaped human history, modern agriculture, free trade, religious freedom, contemporary epidemiology, and political institutions in Ireland, Great Britain, and the United States.

EL-BT is one of the oldest pestilential diseases of humankind.¹ *Rickettsia prowazekii* (*R. prowazekii*) is the etiologic agent of EL-BT. *R. prowazekii* are endogenous bacteria that reside within the human body louse (*Pediculus humanus corporis*). In general, massive population movement, poor hygiene, and famine favor the development of epidemic typhus outbreaks. Moreover, many wars and military invasions were associated with or followed by outbreaks of epidemic typhus. Although historically significant, EL-BT is now considered a relatively rare disease.² However, given today's growing and global population trends, EL-BT ought not to be ignored.

Statement of Problem

The Irish Potato Famine's events impart lessons that contemporary public health policymakers ought to heed. Although louse-borne diseases infected humans for several

¹ Emmanouil Angelakis, Yassina Bechah, and Didier Raoult, "The History of Epidemic Typhus," *Microbiology Spectrum* 4, no. 4 (August 2016), <https://doi.org/10.1128/microbiolspec.PoH-0010-2015>.

² CDC, "Epidemic Typhus | CDC," Centers for Disease Control and Prevention, November 13, 2020, <https://www.cdc.gov/typhus/epidemic/index.html>.

centuries, they remain a significant public health concern in populations living in poor hygiene conditions because of war, social disruption, severe poverty, or public health management gaps. Epidemic typhus could reemerge as a severe epidemic in areas of the world where social strife and underdeveloped public health programs and infrastructure persist. By recognizing risk factors (and developing mitigation strategies) for rickettsial diseases in impoverished communities, public health officials can continue diminishing the threat of one of the most notorious pestilential diseases in history. Historical, "lesson-seeking" evaluations offer multidisciplinary insight for scholars and practitioners within the fields of epidemiology, biosecurity, and public health.

Purpose and Importance of this Study

This thesis examines the determinative factors that give birth to *R. prowazekii* outbreaks in impoverished communities by analyzing a catastrophic and pivotal event in public health history, the Irish Potato Famine of 1848. A historical analysis of the relationship between socio-economic and other risk factors and the opportunity for EL-BT events can shed light on how to prevent and manage future EL-BT outbreaks within at-risk communities. The thesis also serves other incidental but valuable purposes: to give the opportunity (for the author, a scholar interested in the history of veterinary public health) for knowledge growth and skill development. Indeed, by working closely with her advisor, the author has sought to acquire new knowledge and become more proficient at writing.

The mass poverty that Ireland experienced led to a wave of EL-BT. One historian of science outlines that typhus spreads most rapidly in crowding, cold, and poverty conditions. Crowding enhances the inhalation of lice feces from the patient by the next victim; cold weather encourages the constant wearing of clothing and huddling together inside for warmth; poverty makes it likely that there is no change of clothes or opportunity for washing the body or belongings. On this basis, typhus's association with camps, prisons, famines, and mass migration has been common in the last five hundred years.³

³ Margaret Humphreys, "A Stranger to Our Camps: Typhus in American History," *Bulletin of the History of Medicine* 80, no. 2 (2006): 269–90, <https://doi.org/10.1353/bhm.2006.0058>.

In the rural areas of South America, Africa, and Asia, EL-BT is still a threat. During the winter months, EL-BT is wildly infectious when hygiene may be compromised.⁴ In 1997, a significant outbreak associated with refugee camps occurred in Burundi during its civil war.⁵ Reports of a significantly high seroprevalence for epidemic typhus and epidemic relapsing fever in developed countries' homeless populations suggest that these populations remain at high risk for outbreaks.⁶ *R. prowazekii* is also considered a bioterrorism agent due to specific biological features (notably environmental stability and possible aerosolized transmission).⁷ Examining mitigation techniques for a disease that can be severe with a mortality rate of up to 60% without antibiotic treatment and poses a bioterrorism threat is imperative for at-risk populations and global communities⁸.

Research Question and Approach

The author of this thesis and her advisor perceive a worthwhile area of research: The causes and impacts of *R. prowazekii* within impoverished communities. In particular, they find thesis-worthy an investigation of the biological and socio-economic features of EL-BT, both in the mid-19th century Irish diaspora and in other communities and contexts today. To enhance the precision of their research quest, they ask the following research question: "From past and contemporary real-life accounts of *R. prowazekii* events, what is the socio-economic and biological relationship between this disease-causing organism and its affected communities?"

⁴ Didier Raoult, Theodore Woodward, and J. Stephen Dumler, "The History of Epidemic Typhus," *Infectious Disease Clinics of North America* 18, no. 1 (March 2004): 127–40, [https://doi.org/10.1016/S0891-5520\(03\)00093-X](https://doi.org/10.1016/S0891-5520(03)00093-X).

⁵ D. Raoult et al., "Outbreak of Epidemic Typhus Associated with Trench Fever in Burundi," *Lancet (London, England)* 352, no. 9125 (August 1, 1998): 353–58, [https://doi.org/10.1016/s0140-6736\(97\)12433-3](https://doi.org/10.1016/s0140-6736(97)12433-3).

⁶ "Arthropod-Borne Diseases Associated with Political and Social Disorder | Annual Review of Entomology," accessed February 2, 2021, <https://www-annualreviews-org.er.lib.k-state.edu/doi/10.1146/annurev-ento-120709-144739>.

⁷ Abdu F. Azad, "Pathogenic Rickettsiae as Bioterrorism Agents," *Clinical Infectious Diseases* 45 (2007): S52–55.

⁸ Yassina Bechah et al., "Epidemic Typhus," *The Lancet. Infectious Diseases* 8, no. 7 (July 2008): 417–26, [https://doi.org/10.1016/S1473-3099\(08\)70150-6](https://doi.org/10.1016/S1473-3099(08)70150-6).

In this research context, “socio-economic” refers to individuals’ social-economic classification and how that factor influences, perhaps determines disease susceptibility and persistence. *A Dictionary of Epidemiology* defines “socio-economic classification” as an “arrangement of persons into groups according to characteristics such as prior education, occupation, and income.”⁹ Analyzing the socio-economic relationship between host and pathogen susceptibility may help develop effective mitigation strategies that are informed by socio-economic analysis. In this context, the term “biological” refers to specimens, systems, or conditions that may be associated with health outcomes or disease effects. Examples of biological factors analyzed in this thesis are pathogen-host relationships, host-environment relationships, and pathogen-environment relationships.

True to the above-stated research question, this thesis critically examines (a) the Irish Potato Famine (or “the Great Famine” or “the Great Hunger”) and typhus-related events in Ireland and (b) other and more recent instances of typhus outbreaks in impoverished communities. Inevitably, this thesis will touch on concepts related to epidemiology, biosecurity, and public health. However, to avoid a haphazard exploration of such concepts, this thesis unpacks the above-stated research question by pursuing two concrete objectives: (1) identifying cause-effect relationships between social and economic factors and outbreak events, and (2) identifying cause-effect relationships between expressly biological (pathogen, host, and environment) factors and outbreak events. Each historical typhus event will be analyzed and described regarding a relationship(s) between outbreak events and the various contributing socio-economic and/or biological factors. The thesis reviews both primary and secondary sources regarding the biological and socio-economic features (including the possible role of poverty in host susceptibility) of *R. prowazekii* in (a) the mid-19th-century Irish Potato Famine and (b) three recent (contemporary) *R. prowazekii* outbreaks and contexts. Practically speaking, this amounts to four case studies. The research methods for these case studies include documentary analysis, secondary data analysis, and archival study. Primary sources will include first-hand accounts written in personal journals, public health reports, and archived print. Secondary

⁹ Miquel Porta, *A Dictionary of Epidemiology* (Oxford University Press, 2014). Social class, Porta notes, is indeed a predictor of health experiences in populations.

sources will include case studies and peer-reviewed publications. Procurement of these sources comes from academic resource databases and other publicly available publications.

Before launching into the case-study-based analyses (i.e., Chapters 2-3), this thesis pauses to review and summarize the basic biology and socio-economic scholarly consensus about the pathogenesis of Epidemic Louse-Borne Typhus.

Literature Review: *Rickettsia prowazekii* and Epidemic Louse-Borne Typhus, Biology, and Socio-economic Explanations

Throughout history, famine has ravaged even the sturdiest of nations. Egypt, Rome, China, and the British empire experienced food shortages due to failed harvests, disastrous weather conditions, war, or outright governmental mismanagement; all can lead to famine. No matter the cause or location, a historically common disease phenomenon associated with starvation, famine, and general poverty is Epidemic Louse-Borne Typhus.¹⁰ Epidemic typhus, also known as louse-borne typhus, exanthematic typhus, historical typhus, classic typhus, sylvatic typhus, red louse disease, and jail fever, is historically suspected to be responsible for massive mortality in the wake of wars, famines, and migrations.¹¹ The relationship between poverty, war, or famine conditions and the birth of EL-BT is born out in a unique field of study: paleomicrobiology. Paleomicrobiology is an emerging field of research in microbiology devoted to detecting, identifying, and characterizing microorganisms in ancient specimens that can date from centuries to thousands of years in age.¹² Paleomicrobiological methods detected an 18th-century EL-BT outbreak in France. Paleomicrobiology also discovered that EL-BT was imported into Europe by Spanish soldiers returning from America.¹³ Paleomicrobiologists also detected *R.*

¹⁰ Didier Raoult and Véronique Roux, “The Body Louse as a Vector of Reemerging Human Diseases,” *Clinical Infectious Diseases* 29, no. 4 (August 15, 1999): 888–911, <https://doi.org/10.1086/520454>.

¹¹ George Cowan, “Rickettsial Diseases: The Typhus Group of Fevers-a Review,” *Postgraduate Medical Journal* 76, no. 895 (May 2000): 269, <http://dx.doi.org.er.lib.k-state.edu/10.1136/pmj.76.895.269>.

¹² Michel Drancourt and Didier Raoult, “Palaeomicrobiology: Current Issues and Perspectives,” *Nature Reviews. Microbiology* 3, no. 1 (January 2005): 23–35, <https://doi.org/10.1038/nrmicro1063>.

¹³ Didier Raoult and Michel Drancourt, *Paleomicrobiology: Past Human Infections* (Springer Science & Business Media, 2008).

proWazekii in Napoleon's Grand Army's remains in Vilnius, Lithuania, which indicates that Napoleon's soldiers had epidemic typhus.¹⁴ Presumably, these 18th-century EL-BT events were birthed precisely due to the very conditions that scientists now understand give rise to the disease. In 1830, August Hirsch said that "the history of typhus is written in those dark pages of the world's story which tell of the grievous visitations of mankind by war, famine, and misery of every kind."¹⁵

An important early description of typhus is thought to have been made in 1546 by Girolamo Fracastoro, a Florentine physician, in his treatise on infectious diseases, *De contagione et contagiosis morbis*. Among the diseases that appeared for the first time in Italy or were first studied in this century was typhus fever. His observations during the Italian outbreaks in 1505 and 1528 allowed him to separate typhus from the other pestilential diseases.¹⁶ Epidemic typhus was often confused with typhoid fever until the 18th century. In 1739 John Huxam, an English surgeon, made an important distinction between the two fevers.¹⁷ Huxam categorized fevers into two essential distinctions, "inflammatory" and "low nervous."¹⁸ He noted that epidemic typhus infections presented with a rash, and post-mortem examinations indicated patients lacking specific ulcerations, contrary to patients with typhoid fever.¹⁹

The human body louse (*Pediculus humanus corporis*) transmits typhus; Charles Nicolle demonstrated this at the Pasteur Institute in Tunis in 1909.²⁰ The scholarly discipline of microbiology has established that *R. prowazekii* is a gram-negative species of obligate

¹⁴ Raoult et al., "Outbreak of Epidemic Typhus Associated with Trench Fever in Burundi."

¹⁵ Peter L. Perine et al., "A Clinico-Epidemiological Study of Epidemic Typhus in Africa," *Clinical Infectious Diseases* 14, no. 5 (1992): 1149–58. Quote on pg 1149.

¹⁶ Raoult, Woodward, and Dumler, "The History of Epidemic Typhus."

¹⁷ Sidney Lee, ed., "Huxham, John," in *Dictionary of National Biography, 1885-1900* (London: Elder Smith & Co., 1891), Wikisource.

¹⁸ John Huxham, *An Essay on Fevers* (S. Austen, 1750).

¹⁹ T. E. Woodward, "Typhus Verdict in American History.," *Transactions of the American Clinical and Climatological Association* 82 (1971): 1–8.

²⁰ L. Gross, "How Charles Nicolle of the Pasteur Institute Discovered That Epidemic Typhus Is Transmitted by Lice: Reminiscences from My Years at the Pasteur Institute in Paris," *Proceedings of the National Academy of Sciences of the United States of America* 93, no. 20 (October 1, 1996): 10539–40, <https://doi.org/10.1073/pnas.93.20.10539>.

intracellular parasitic bacillus bacteria that causes EL-BT.²¹ Henrique da Rocha Lima, a Brazilian doctor, discovered that *R. prowazekii* inside the body louse was EL-BT's causative agent in 1916. Rocha Lima named the bacteria after Stanislaus von Prowazek, a doctor who had died from typhus in 1915. Both Prowazek and Rocha Lima had been infected with typhus while studying its causative agent in a prison hospital in Hamburg, Germany.²²

The human body louse transmits EL-BT by growing *R. prowazekii* in its digestive tract and excreting the bacteria in its feces.²³ The louse itself suffers from the *R. prowazekii* infection, and depending on the number of bacteria in its gut, the infection can kill the louse within one week.²⁴ Professor Hans Zinsser thus describes the fate of the typhus-stricken louse: "In eight days he sickens, in ten days he is in extremis, on the eleventh or twelfth day his tiny body turns red with blood extravasated [forced out] from his bowel, and he gives up his little ghost."²⁵ The louse transmits the bacteria by biting an uninfected human, who scratches the louse bite and rubs the feces into the wound. EL-BT contraction can occur via aerosolization of the louse's infected fecal matter; louse infestation is unnecessary for EL-BT contraction.²⁶ Person-to-person transmission requires close personal contact or sharing of personal items. In the United States, the southern flying squirrel, *Glaucomys volans*, serves as the only known vertebrate zoonotic reservoir for *R. prowazekii*.²⁷ Brill-Zinsser disease is a delayed relapse of epidemic typhus, where the bacteria remains latent for months or even years after the initial infection.²⁸ (See Figure 1 for a depiction of the complex lifecycle of *R. prowazekii*.)

²¹ David H. Walker, "Rickettsiae," in *Medical Microbiology*, ed. Samuel Baron, 4th ed. (Galveston (TX): University of Texas Medical Branch at Galveston, 1996), <http://www.ncbi.nlm.nih.gov/books/NBK7624/>.

²² Mary Dobson, *Murderous Contagion: A Human History of Disease* (Quercus Publishing, 2015)

²³ Linda Houhamdi et al., "An Experimental Model of Human Body Louse Infection with *Rickettsia Prowazekii*," *The Journal of Infectious Diseases* 186, no. 11 (December 2002): 1639–46, <https://doi.org/10.1086/345373>.

²⁴ Houhamdi et al.

²⁵ Cecil Woodham Smith, *The Great Hunger: Ireland 1845-1849* (Harper & Row, 1962).

²⁶ Bechah et al., "Epidemic Typhus."

²⁷ "Epidemic Typhus Associated with Flying Squirrels -- United States," accessed February 15, 2021, <https://www.cdc.gov/mmwr/preview/mmwrhtml/00001177.htm>.

²⁸ "Definition of Brill-Zinsser Disease," accessed March 22, 2021, https://www.medicinenet.com/brill-zinsser_disease/definition.htm.

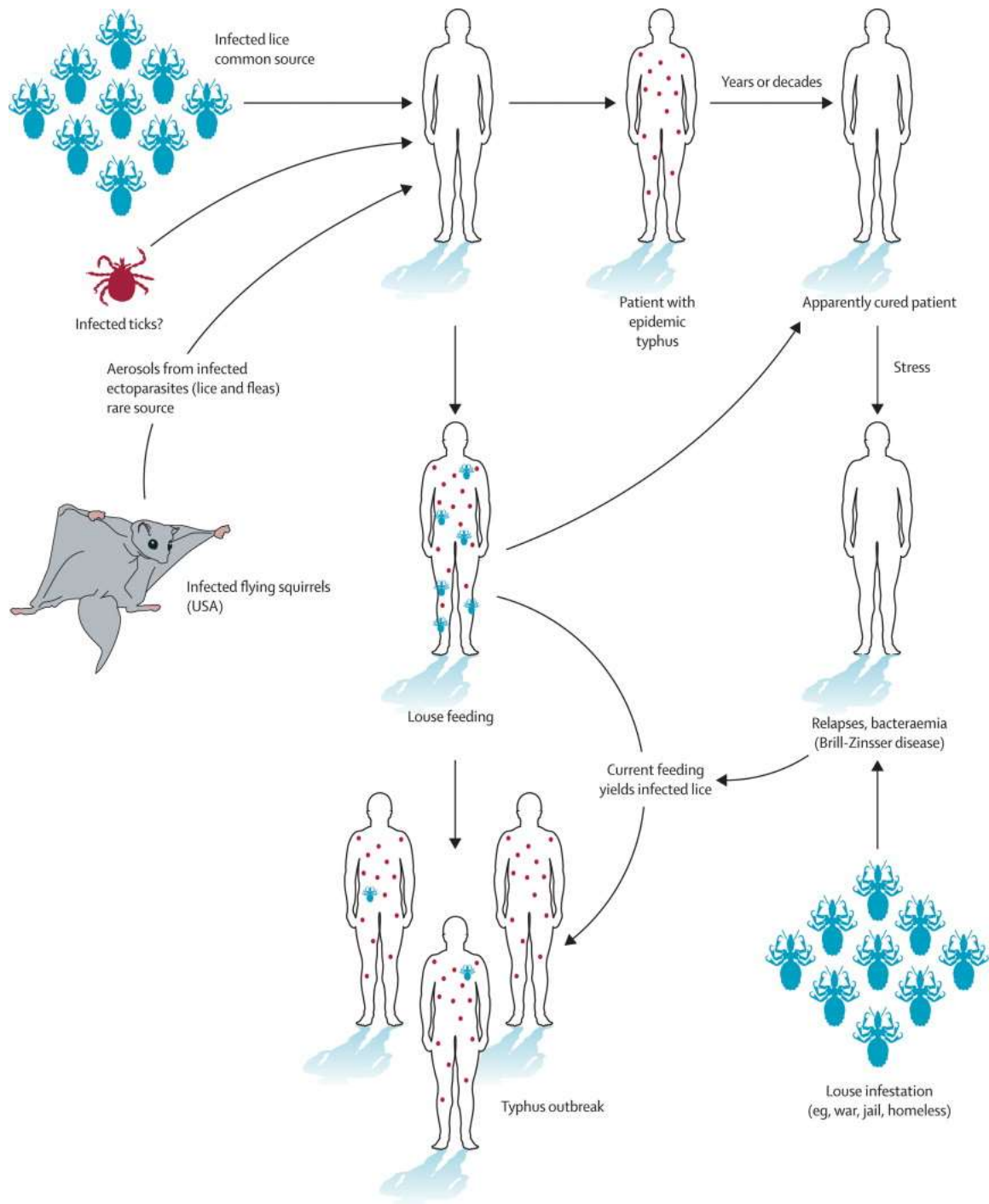


Figure 1 Lifecycle of *R. prowazekii* (Source: Bechah et al.)²⁹

²⁹ Bechah et al., "Epidemic Typhus."

Interestingly, EL-BT is usually spread during the cold winter months when crowding and the need for multiple layers of clothing facilitate lice proliferation.³⁰ Indeed, epidemic typhus generally occurs in outbreaks when poor sanitary conditions and overcrowding are present. Dwindling strength and poverty prevents an often taken-for-granted sanitary practice: changing clothes and bathing. Without antibiotic treatment, mortality rates for EL-BT can be 60%. However, antibiotics and supportive treatment can lower mortality to below 5%.³¹ Due to its capacity to spread in vulnerable populations, EL-BT is still a concern for the healthcare sector and public health officials.

Epidemic typhus and other arthropod-borne diseases are generally associated with political and social disorder.³² Of course, armed conflict and war have an undisputed effect on poverty itself.³³ Consequently, poverty may be seen as both a cause and a consequence of armed conflict and war. EL-BT's link to war is historically demonstrated near the end of the Napoleonic Wars when the Grand Army marched to Moscow with approximately 500,000 to 700,000 men, but only 3,000 men returned.³⁴ 20% of the troops likely died from epidemic typhus.^{35,36} Following World War I, the United States, Eastern Europe, and Russia saw 25 million cases and

³⁰ Aurélié Renvoise and Didier Raoult, "61 - Epidemic Louse-Borne Typhus," in *Hunter's Tropical Medicine and Emerging Infectious Disease (Ninth Edition)*, ed. Alan J. Magill et al., Ninth Edition (London: W.B. Saunders, 2013), 535–38, <https://doi.org/10.1016/B978-1-4160-4390-4.00061-8>.

³¹ Bechah et al., "Epidemic Typhus."

³² "Arthropod-Borne Diseases Associated with Political and Social Disorder | Annual Review of Entomology."

³³ Thomas Fürst et al., "Effect of an Armed Conflict on Relative Socioeconomic Position of Rural Households: Case Study from Western Côte d'Ivoire," *Emerging Themes in Epidemiology* 7, no. 1 (August 31, 2010): 6, <https://doi.org/10.1186/1742-7622-7-6>.

³⁴ Raoult, Woodward, and Dumler, "The History of Epidemic Typhus."

³⁵ Hans Zizsser, *Rats, Lice and History* (Read Books Ltd, 2012).

³⁶ A. L. Gelston and T. C. Jones, "Typhus Fever: Report of an Epidemic in New York City in 1847," *The Journal of Infectious Diseases* 136, no. 6 (December 1977): 813–21, <https://doi.org/10.1093/infdis/136.6.813>.

3 million deaths from 1917-1925.^{37,38} During World War II, the disease also prevailed in concentration camps through Europe and northern Africa.³⁹

In addition to war, famine and poverty have received scholarly attention for their impact on EL-BT disease events. The Hunger Project, a non-profit organization, has aptly emphasized the reinforcing dynamics of hunger and poverty: “Not every person living in poverty faces chronic hunger, but almost all people facing chronic hunger are also living in poverty.”⁴⁰ EL-BT’s link to famine was devastatingly demonstrated in Ireland during the Irish Potato Famine of 1847, an event focused on in this thesis. The Irish Potato Famine was a prime example of how poverty and hunger reinforce each other and, significantly, led to disease epidemics, including EL-BT. Following the outbreak in Ireland, mass migration led to the North American Typhus Epidemic of 1847. Historical and retrospective climate analysis shows that crop failure and famine were significant factors in typhus epidemics in Mexico from 1655-1918.⁴¹ Dr. Newsholme, President of the Epidemiological Section of the new Royal Society of Medicine, argued, “Poverty and disease are allied by the closest bonds, and nothing can be simpler or more certain than the statement that the removal of poverty would [affect] an enormous reduction of disease.”⁴²

Contemporarily, outbreak events of EL-BT are linked to homelessness (a common feature of poverty). Homeless populations are at an elevated risk of typhus contraction since the

³⁷ Hans Zinsser, “Varieties of Typhus Virus and the Epidemiology of the American Form of European Typhus Fever (Brill’s Disease),” *American Journal of Epidemiology* 20, no. 3 (1934): 513–32.

³⁸ “Typhus - New World Encyclopedia,” accessed March 26, 2021, <https://www.newworldencyclopedia.org/entry/typhus>.

³⁹ “World War II: Typhus Fever and Malaria in the Mediterranean,” Fred L. Soper - Profiles in Science, accessed March 20, 2021, <https://profiles.nlm.nih.gov/spotlight/vv/feature/typhus>.

⁴⁰ “Poverty,” *The Hunger Project* (blog), accessed March 21, 2021, <https://thp.org/what-we-do/issues/poverty/>.

⁴¹ Jordan N. Burns, Rodolfo Acuna-Soto, and David W. Stahle, “Drought and Epidemic Typhus, Central Mexico, 1655-1918,” *Emerging Infectious Diseases* 20, no. 3 (March 1, 2014): 442–48.

⁴² “Poverty and Disease, as Illustrated by the Course of Typhus Fever and Phthisis in Ireland,” *Proceedings of the Royal Society of Medicine* 1, no. Sect Epidemiol State Med (1908): 1–44.

human body louse lives and multiplies in clothing in poor and unhygienic conditions.⁴³ Recently, a typhus epidemic affected parts of the homeless population in California.⁴⁴ In his State of the State speech in February 2019, California Governor Gavin Newsom said, citing typhus outbreaks in Los Angeles County, “Typhus. A medieval disease. In California. In 2019.”⁴⁵ Marginalized people living in precarious sanitary and degraded socio-economic conditions, refugees from civil wars, prisoners in jails, and homeless individuals all appear to be at high risk of contracting EL-BT.

In addition to the well-established biological explanations, it appears that war, famine, general poverty, and homelessness emerge as disruptive influences on the socio-economic status of a population and, in keeping with long-understood determinants of health, increase the risk of disease susceptibility. While this generally seems evident and applicable to a myriad of diseases, this thesis seeks to unearth *additional and/or more precisely identified* socio-economic and biological factors that give rise to EL-BT. By analyzing historical and contemporary cases of EL-BT events, and in keeping with our "Research Question and Approach" described above, this thesis features (beyond this one) three chapters. Chapters 2 and 3 will summarize historical and recent EL-BT event(s) and, inductively (based on a reading of the historical or contemporary cases), highlight and specify cause-effect relationships (both socio-economic and biological) with regard to EL-BT. By doing so, the author of this thesis will likely confirm existing disease-causation understandings (i.e., those described in this current chapter) but also, perhaps, note neglected socio-economic and/or biological causative factors worthy of the attention of public health scholars and practitioners. Chapter 4 then catalogs and interprets these factors that have emerged from our analysis.

⁴³ Amina Boutellis, Laurent Abi-Rached, and Didier Raoult, “The Origin and Distribution of Human Lice in the World,” *Infection, Genetics and Evolution* 23 (April 2014): 209–17, <https://doi.org/10.1016/j.meegid.2014.01.017>.

⁴⁴ Anna Gorman News Kaiser Health, “‘Medieval’ Diseases Flare as Unsanitary Living Conditions Proliferate,” *Scientific American*, accessed March 22, 2021, <https://www.scientificamerican.com/article/medieval-diseases-flare-as-unsanitary-living-conditions-proliferate/>.

⁴⁵ “Governor Newsom Delivers State of the State Address,” California Governor, February 12, 2019, <https://www.gov.ca.gov/2019/02/12/state-of-the-state-address/>.

Chapter 2 - The Irish Potato Famine and Epidemic Louse-Borne Typhus

“We are a vibrant first-world country, but we have a humbling third-world memory.”

- Mary McAleese, 8th President of Ireland from 1997 to 2011⁴⁶

Historical Context

Chapter 1 gave voice to the long-accepted connection between famine and EL-BT events. This chapter explores a well-known famine event also connected to the emergence of EL-BT: the Irish Potato Famine. The Irish Potato Famine, also known as the Great Hunger, started in 1845 when *Phytophthora infestans* (or *P. infestans*), a fungus-like organism, spread rapidly across Ireland.⁴⁷ The infestation destroyed half of the potato crop that year and three-quarters of the crop for the next seven years. The infestation had a devastating effect on Ireland and its population because tenant farmers in Ireland—then governed as a British colony—were heavily reliant on the potato as a food source. The Potato Famine and the EL-BT events caused an estimate of over one million Irish lives, with approximately another million forced to flee their homeland as refugees. To understand how Ireland became practically solely dependent on one crop, one must understand England and Ireland's political conflicts throughout history. The English-Irish dysfunctional relationship started in 1169 with the Norman invasion of Ireland.⁴⁸ England ruled Ireland with the assistance of an English-crafted Irish Parliament, located in Dublin. In 1559, the English monarch, Elizabeth I, decreed Roman Catholicism to be illegal via the Act of Uniformity.⁴⁹ The Irish, being predominantly Catholic, were, understandably, moved

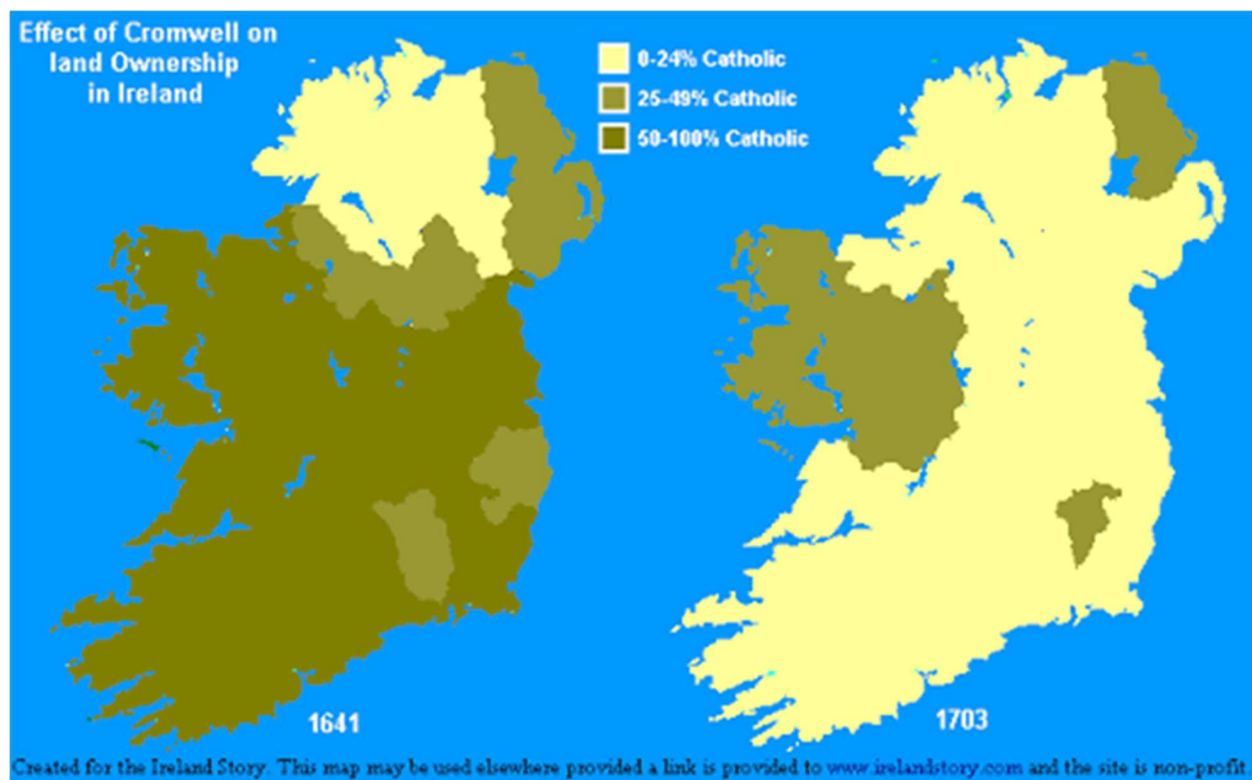
⁴⁶ Office of the President of Ireland, “Media Library | Speeches | President of Ireland,” accessed March 26, 2021, <https://president.ie/index.php/en/media-library/speeches/remarks-by-president-mcaleese-at-the-world-affairs-council-los-angeles>.

⁴⁷ “Irish Potato Famine - Timeline, Causes & Facts - HISTORY,” accessed March 30, 2021, <https://www.history.com/topics/immigration/irish-potato-famine>.

⁴⁸ T. W. Moody, F. X. Martin, and F. J. Byrne, *A New History of Ireland: Volume III: Early Modern Ireland 1534-1691: Early Modern Ireland 1534-1691* (OUP Oxford, 2009).

⁴⁹ Moody, Martin, and Byrne.

to rebellion. Ireland consistently resisted English rule, and multiple conflicts ensued over the next several centuries. In 1609, Irish lands were effectively transferred and redistributed via the Plantation of Ulster, giving land-holding rights to English landlords.⁵⁰ This economic-power transfer led to the Irish Rebellion of 1641, pitting the Irish Catholics against the Protestant English.⁵¹ The Irish Confederate Wars and, ultimately, the War of the Three Kingdoms followed this rebellion. The apex of Ireland's conflict with England arguably came with the conquest of Ireland by Oliver Cromwell in 1649. Cromwell's mission was to "eradicate the Irish problem" in the name of God. As a part of his murderous invasion, he burned fields, poisoned well water, salted land, and uprooted crops. He also stole farmland from Irish owners and sold it to English compatriots. His aggressive push drove most Irish Catholics to Ireland's far west side, where the land featured poor growing conditions (Figure 2). These conflict-filled events all but guaranteed Ireland's eventual agricultural woes.



⁵⁰ Jonathan Bardon, *The Plantation of Ulster: The British Colonisation of the North of Ireland in the Seventeenth Century* (Gill & Macmillan, 2011).

⁵¹ Moody, Martin, and Byrne, *A New History of Ireland*.

Figure 2—Two-in-one map of Ireland in 1641 and 1703 indicating the effect of Oliver Cromwell's period of rule of Britain and Ireland. It compares the proportion of land in each county in Ireland owned by Roman Catholics.⁵²

An outspoken advocate of Cromwellian rule predicted the Irish would become "insignificant slaves." Penal laws prevented Catholics from holding public office, serving in the military, owning property, voting, participating in open commerce, publishing books, teaching, attending school, speaking their native language of Gaelic, and freely worshipping. These laws put future generations at a severe disadvantage and hopelessly dependent on British aid. Anyone found disobeying these laws was tried and either executed or sold to America as indentured servants. The Irish responded to these laws with contempt, rage, and threats of revenge. The already impoverished lower class and a newly impoverished middle class forcibly surrendered their land to British landlords. Only those few Irish land-holders in the west maintained control over their land: however, as already explained, they faced insurmountable agricultural challenges. Western Ireland's topography consists of coastal mountains, marshlands, and numerous lakes, as pictured in Figure 3. Figure 4 demonstrates the severity of famine within western Ireland by outlining the percentage of the people who took up rations in 1847. 100% of western Ireland's population had to rely on food rations during the famine, most likely due to the inability to grow sufficient crops.

⁵² "Free Maps of Ireland," accessed February 8, 2021, http://www.wesleyjohnston.com/users/ireland/map_index.html#historical.



Figure 3—A boggy patch of land in County Roscommon.⁵³

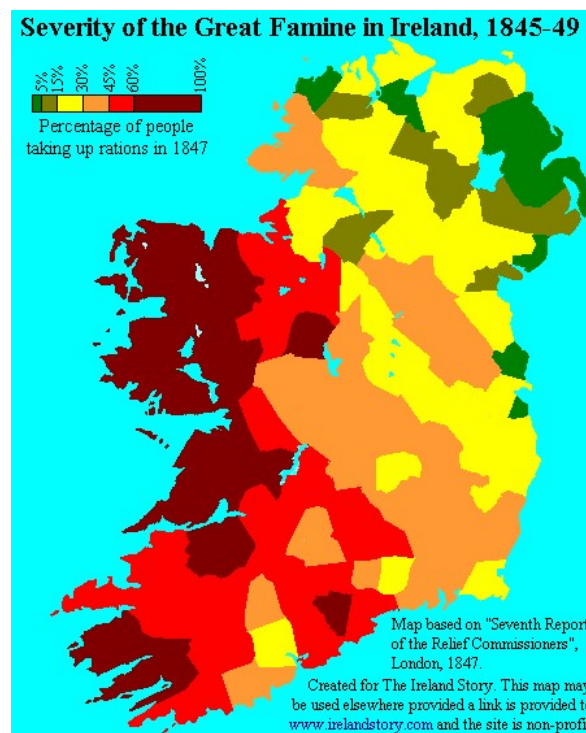


Figure 4—Percentage of people taking up rations in 1847.⁵⁴

⁵³ "Potato Famine Facts," Enjoy Irish Culture, accessed April 1, 2021, <https://www.enjoy-irish-culture.com/Potato-Famine.html>.

⁵⁴ "The Irish Famine: Distribution of Famine Effects," accessed April 1, 2021, <https://www.wesleyjohnston.com/users/ireland/past/famine/distribution.html>.

France aided Ireland in one of its uprisings against British rule. The so-called United Irishmen was a revolutionary group inspired by French and American revolutionaries' actions.⁵⁵ The rebellion suffered significant losses, with the death toll reaching 50,000 Irish casualties. Immediately following this devastation, the British and Irish parliaments reluctantly but necessarily sought a “way forward” with the Act of Union in 1801.⁵⁶ This act was passed in the Irish Parliament primarily because only those politically (and religiously) allied with England were allowed to become members of the Irish Parliament; of course, most of Ireland was Roman Catholic. The Act of Union amounted to the Irish Parliament's dissolution, moving Ireland's government from Dublin to London. With one unifying government, economic and political thought leaders hoped that free trade would flourish, England would increase investment into Irish agriculture and infrastructure, and Irish politicians would happily serve in the British Parliament. Dublin, the former home to the Irish Parliament, was described as “the half-dead city” after Ireland's political autonomy dissolution. The Act of Union stripped away Irish Catholics' ability to hold office and practice freedom of religion, promised but stricken before passed. This betrayal left Irish Catholics helpless, hostile, poverty-stricken, and still rebellious.

In 1845, the British Parliament established the Devon Commission to examine the issues regarding land ownership throughout Ireland.⁵⁷ The secretary of this commission, John Pitt Kennedy, wrote pamphlets distributed to British landlords entitled, “Instruct, Employ, Don't Hang Them—or Ireland Tranquilized Without Soldiers, and Enriched Without English Capital.”⁵⁸ The investigation discovered the root of the issue—Ireland was a conquered land; most of Ireland's landowners were non-nationals who acquired land through Cromwellian

⁵⁵ David Dickson, Dáire Keogh, and Kevin Whelan, *The United Irishmen: Republicanism, Radicalism, and Rebellion* (Lilliput Press, 1993).

⁵⁶ Patrick M. Geoghegan, *The Irish Act of Union: A Study in High Politics, 1798-1801* (Gill & Macmillan, 2001).

⁵⁷ Catharine Anne Wilson, *New Lease on Life: Landlords, Tenants, and Immigrants in Ireland and Canada* (McGill-Queen's Press - MQUP, 1994).

⁵⁸ John Pitt Kennedy, *Instruct, Employ, Don't Hang Them: Or, Ireland Tranquilized Without Soldiers and Enriched Without English Capital, Containing Observations on a Few of the Chief Errors of Irish Government and Irish Land Proprietors, with the Means of Their Correction Practically Illustrated* (T. and W. Boone, 1835).

confiscation or conquest. Many owners lived abroad and focused solely on profit margins rather than maintaining their property or their tenants' well-being. As coined by Irish peasants, land stewards, or "land sharks," were left to manage the property in the owners' absence.⁵⁹ Land stewards would split farm plots into smaller holdings to be able to rent to multiple families. The stewards rented the holdings at hyperinflated prices and sometimes rented to two or more families. One case documented eight families living in a single-family home, and several members worked a plot barely suitable for a single-family. Stewards' jurisdiction had few regulations, and the more land that was split and inflated, the more profits increased. This perpetuation of what might be appropriately called "slumlord land management" crippled an already crippled economic system. The population density that ensued also contributed to the eventual EL-BT epidemic described below.

Proper leasing systems did not exist for Irish farmers. Without tenant rights or leasing protection, landlords and stewards could issue eviction notices at a moment's notice. Irish farmers were left vulnerable to predatory practices and price gouging. A tenant's debt would increase as rent continually increased. A year's harvest often could not match the cost of living and, if a tenant's debt accumulated too long, the family faced eviction. Evicted farmers became vagrants, resorted to begging in desperation, and were at risk of disease and starvation. An economist who observed this economic calamity commented, "This debt hangs over their heads and keeps them in a perpetual state of anxiety and terror."⁶⁰ Evictions led to an increasing number of homeless Irish in poverty. Benjamin Disraeli, the British Prime Minister, documented in 1847 that Ireland was the most densely populated country in Europe. However, the census could not accurately account for many Irish families due to increasing homelessness. The Devon Commission, the British Parliament's commission to investigate agricultural disparities in Ireland, found that the people of Ireland were "enduring sufferings greater than any other people in Europe."⁶¹

⁵⁹ Hely Dutton Dutton, *A Statistical and Agricultural Survey of the County of Galway* (Lulu.com, 2013).

⁶⁰ Godfrey Locker Lampson, *A Consideration of the State of Ireland in the Nineteenth Century* (A. Constable, 1907).

⁶¹ William Edward Hearn, *The Cassell Prize Essay on the Condition of Ireland* (J. Cassell, 1851).

Laws preventing open commerce among Irish Catholics, disparate land ownership, and ill maintenance of rented farmland caused Ireland's agricultural economy to stagnate. British landlords received meager profits from rented farmland in England. Instead of investing back into Irish infrastructure, any profits (controlled by English landlords and businessmen) were spent and invested in the British economy. This model was unsustainable and unjust. One report showed that in 1842 £6 million in rent left Ireland, paying British landlords in England.⁶²

With poverty and homelessness increasing throughout Ireland and laws that prohibited Irish Catholics from attending school, a massive vagrant force of unskilled workers emerged. Lack of investment by Britain in other industrial infrastructure left few options for employment. Agriculture offered one of the few profitable economic vocations in Ireland. British factories largely controlled textile manufacturing.⁶³ There was no room for developing textile businesses in Ireland because England's factory network met Ireland's demand. With few alternatives to generate revenue, Ireland depended on its land for economic stimulus. With land representing the only viable industry, land became extremely valuable. Rent prices for farmland were 80-100% higher than English farmland.⁶⁴ Farming had its limitations. The growing and harvest season for potatoes lasted 30 weeks out of the year, leaving farmers out of work for 22 weeks.⁶⁵ Farmhands with no other experience were not employable in the offseason, and unemployment rates remained perpetually high. In 1840, approximately 2,300,000 people were unemployed, about 25-35% of the working-age population.⁶⁶

Along with employment rates rising, birth rates in Ireland were also increasing. From 1779-1841, Ireland's population grew 172% (Figure 5).⁶⁷ Access to healthcare facilities aiding in

⁶² Mike Commings, *Northern Ireland-Britain's Legacy* (Resourcefulmedia.uk, 2019).

⁶³ "BBC - History - British History in Depth: Symbiosis: Trade and the British Empire," accessed March 15, 2021, http://www.bbc.co.uk/history/british/empire_seapower/trade_empire_01.shtml.

⁶⁴ Marina Manoukian, "Boycott: The Wild Origins Of The Term Explained," Grunge.com, March 24, 2021, <https://www.grunge.com/363915/boycott-the-wild-origins-of-the-term-explained/>.

⁶⁵ "Potatoes - Teagasc | Agriculture and Food Development Authority," accessed March 26, 2021, <https://www.teagasc.ie/crops/crops/potatoes/>.

⁶⁶ Smith, *The Great Hunger*.

⁶⁷ "Ireland's History in Maps (1841 AD)," accessed January 29, 2021, <http://sites.rootsweb.com/~irlkik/ihm/ire1841.htm>.

both the poverty and the maternal health care crises dwindled. In 1841 there were only 39 hospitals in operation to service 8.2 million Irish.⁶⁸ The infant mortality rate (the percentage of infants who die before reaching one) in 1840 was 20%.⁶⁹ With job insecurity and limited healthcare access, the population grew due to the land ownership system. Families needed to bear more children to avoid the employment cost of farmhands and avoid elderly eviction due to the inability to keep the farm in sustainable production. Irish youth were married young, around 15-16 years old.⁷⁰ Arthur Young, a traveler, noted the increased birth rates in Ireland, stating, "19-20 of them breed every two years. Long live the potato!"⁷¹

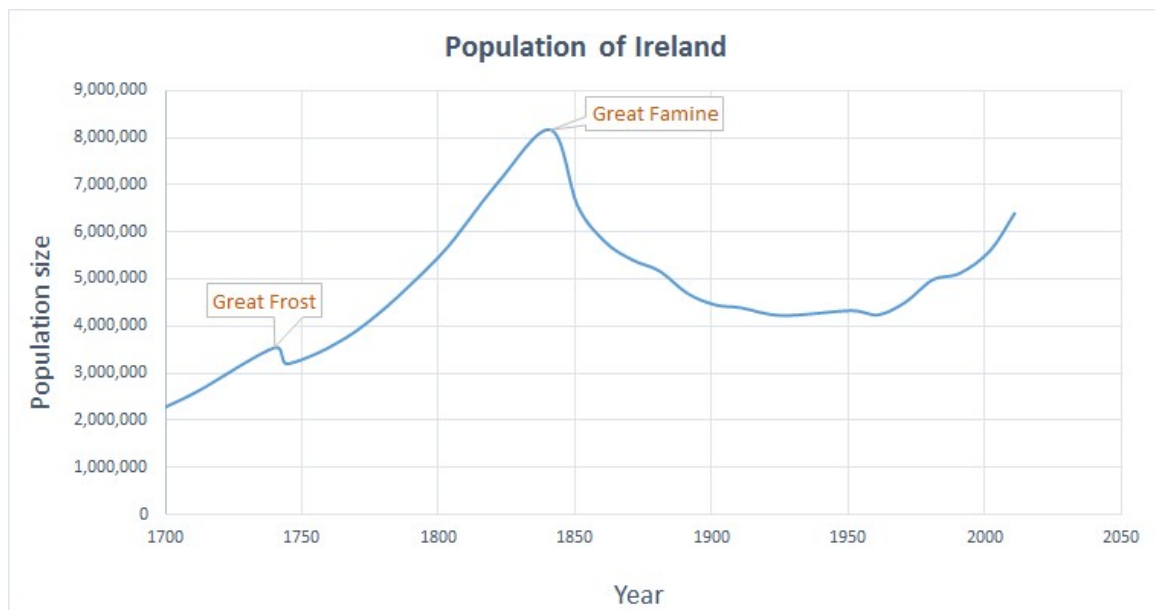


Figure 5 The population of Ireland throughout history.⁷²

⁶⁸ Timothy P. O'Neill, "Fever and Public Health in Pre-Famine Ireland," *The Journal of the Royal Society of Antiquaries of Ireland* 103 (1973): 1–34.

⁶⁹ McDannell, Colleen. *The Christian Home in Victorian America, 1840--1900*. Ukraine, Indiana University Press, 1994.

⁷⁰ Kenneth Hugh Connell, *The Population of Ireland, 1750-1845* (Greenwood Press, 1975).

⁷¹ A Tour in Ireland. Accessed December 19, 2020. <https://www.gutenberg.org/files/22387/22387-h/22387-h.htm>

⁷² "Ireland's Population in the Mid 1800's," accessed March 15, 2021, https://www.mapspictures.com/ireland/history/ireland_population.php.

As long as the land and weather cooperated with the growing season, farmers consistently and abundantly harvested potatoes. It was a staple in agriculture, trade, and nutrition. It was cheap, abundant, and nutritious. The traditional Irish diet consisted of "the potato mixed with a little buttermilk; it provided all the nutrients the body needs to survive."⁷³ Pigs and cattle could be fed potatoes, and it did not require much farmland to grow in abundance. Harvest only required a spade, so complex farming equipment was not necessary. As long as the crop did not fail, the Irish could survive effectively despite all the cards stacked against them.

The potato came with its own set of unique problems that the Irish peasantry could not resolve. First of all, the potato did not store well. Unlike grain, the potato was unable to be kept year-round. The entire crop would safely keep for six months before rotting.⁷⁴ The last season's crop was either sold, eaten, or rotten by the summer, leaving the Irish population with little food. Seasonal starvation became a dangerous yet accepted part of the peasantry's calendar. Secondly, the potato carried a high risk of disease and total crop failure. This tuber had several incidents of total crop failure in Ireland before the Irish Potato Famine. Eleven complete crop failures occurred in Ireland between 1728-1837.⁷⁵ Lastly, there was no replacement for the potato in Ireland. No grain was as cheap, and all grains required more land than the potato. Farmers could not survive off the small amount of wheat they could grow on their sub-divided land plots. With no replacement, the Irish became solely dependant on this dangerously unstable crop.

The British Parliament studied these problems in the early 1830s. Many politicians blamed Irish peasants for their dependency on the potato, calling them lazy or too stupid to grow different crops.⁷⁶ Parliament claimed that it was the peasants' fault for coming so close to starvation every year. The government refused to send aid during the offseason even though the British Parliament swore to take full responsibility for the Irish people starting in 1801. The

⁷³ Food in Ireland 1600 - 1835. Accessed December 19, 2020. <https://www.dochara.com/the-irish/food-history/food-in-ireland-1600-1835/>

⁷⁴ A. Rastovski and A. van Es, *Storage of Potatoes: Post-Harvest Behaviour, Store Design, Storage Practice, Handling* (Centre for Agricultural Publishing and Documentation, 1981).

⁷⁵ Maranzani B. After 168 Years, Potato Famine Mystery Solved. HISTORY. Accessed December 19, 2020. <https://www.history.com/news/after-168-years-potato-famine-mystery-solved>

⁷⁶ Tim Pat Coogan, *The Famine Plot: England's Role in Ireland's Greatest Tragedy* (St. Martin's Publishing Group, 2012).

unemployed received no benefits, and the workhouses were scarce across the country. The Irish, systematically discriminated against in their own country, continued to starve every year and were subjected to legalized monopolies and oppressive practices. These events and circumstances would prove to be precursors to the Irish Potato Famine.

One more catastrophe would drive Ireland over its tipping point. In 1844, this disaster arrived in the form of a government report from North America.⁷⁷ A new disease blighted American potato crops, and the United States was losing entire harvests. Ireland needed to heed this warning.

The Irish Potato Famine and EL-BT Epidemic

As already noted, the Irish potato crop has failed several times throughout the country's history.⁷⁸ Partial or total crop failures resulted in severe famine. However, Ireland established the potato as the only crop hearty enough to meet the needs of the millions of desperately poor Irish tenant farmers on their small sub-divided farm plots, living under constraints imposed by absentee landlords. Despite the potato's past failures, there was no replacing the crop. The unreliability of this necessary commodity was an accepted and lamented fact in Ireland.

In July 1845, the crop seemed healthy and strong. The weather provided the potato's ideal growing conditions: hot and dry summer days through the midseason. A short 3-week period of heavy rains in July was the only hindrance in the summer of 1845.⁷⁹ Despite slight flooding, the crops seemed robust. *The Freeman's Journal*, the oldest nationalist newspaper in Ireland, predicted, "1845 will be a year of plenty."⁸⁰

In August 1845, the first signs of disaster were trickling in. *P. infestans*, or potato blight, was reported in potato crops on the Isle of Wight, a small island off England's coast.⁸¹ As a result, the Isle of Wight reported fields of rotting potatoes and a near-total crop loss. Reports

⁷⁷ Smith, *The Great Hunger*.

⁷⁸ Smith.

⁷⁹ "The Origin of Plant Pathology, Potato Famine, Downy Mildew of Grapes and Tree Diseases," accessed March 10, 2021, <http://www.botany.hawaii.edu/faculty/wong/BOT135/LECT06.HTM>.

⁸⁰ Smith, *The Great Hunger*. p.39

⁸¹ "The Great Famine of 1845," History Learning Site, accessed March 10, 2021, <https://www.historylearningsite.co.uk/ireland-1845-to-1922/the-great-famine-of-1845/>.

from other countries of *P. infestans* outbreaks were just as devastating. Belgium recorded a total crop loss by the end of August.⁸² Farmers saw this desolation "seemingly overnight," and botanists across Europe requested ideas and solutions from other scientists and scholars.⁸³

Despite crop destruction across Europe in August, there was no reported *P. infestans* outbreak in Ireland, and the projected crop yields remained optimistically high. Unfortunately, in September of 1845, *P. infestans* made its first appearance in Ireland.⁸⁴ The initial infection occurred in Dublin fields; the country remained hopeful of avoiding a *P. infestans* outbreak. On September 25th, banker Robert Murray wrote to the government, stating, "The potato crop's alleged failure was very greatly exaggerated."⁸⁵ In many parts of Ireland, the crop remained strong even through mid-October. As the harvest began, several counties reported total or near-total crop loss.⁸⁶ For many citizens, this also meant the destruction of their only food supply. In some counties, the crop was healthy and harvestable but would succumb to rot days later.⁸⁷ This created mass contradictions as optimists reported robust and healthy crops while the government sorted through pleas for aid.

Meanwhile, British scientists and scholars started to issue remedies for potato blight. Dr. Lyon Playfair, a British scientist, suggested a chemical treatment to prevent the potatoes from rotting.⁸⁸ The Prime Minister, Sir Robert Peel, created an official commission to investigate scientific means to save the potato crop. The commission sent Playfair to Ireland along with several other English scientific minds. After arrival, the scholars quickly reported to England, urging the Prime Minister to take this matter seriously. Playfair wrote, "the accounts are

⁸² J. C. Zadoks, "The Potato Murrain on the European Continent and the Revolutions of 1848," *Potato Research* 51, no. 1 (March 2008): 5–45, <https://doi.org/10.1007/s11540-008-9091-4>.

⁸³ John Kelly, *The Graves Are Walking: The Great Famine and the Saga of the Irish People* (Henry Holt and Company, 2012).

⁸⁴ "The History Place - Irish Potato Famine: The Blight Begins," accessed March 10, 2021, <https://www.historyplace.com/worldhistory/famine/begins.htm>.

⁸⁵ Ben Kiernan, "From Irish Famine to Congo Reform: Nineteenth-Century Roots of International Human Rights Law and Activism," 2011, 13–43, https://doi.org/10.1007/978-90-481-9840-5_2.

⁸⁶ Smith, *The Great Hunger*.

⁸⁷ Zadoks, "The Potato Murrain on the European Continent and the Revolutions of 1848."

⁸⁸ Thomas P. O'Neill, "The Scientific Investigation of the Failure of the Potato Crop in Ireland, 1845-6," *Irish Historical Studies* 5, no. 18 (1946): 123–38.

underrated rather than exaggerated."⁸⁹ The commission discovered that *P. infestans* destroyed more than half of Ireland's potato crop.

The commission immediately circulated a series of pamphlets with suggestions to Irish farmers on circumventing the threat. None of these recommendations alleviated *P. infestans*; they only offered a list of suggestions on uses for blighted potatoes. For example, the commission suggested the following steps for farmers in case their crops became blighted. First, dry the rotten potatoes in the sun, then place them in a shallow pit. Next, cover them in sod, lye, and dried sawdust. After a while, grate the diseased potatoes in a tub of water, wash and strain the pulp. The water used will be milky white with potato starch, remove the starch, and make bread.⁹⁰ Nutritional knowledge of the time proved that bread alone was not enough to feed humans or livestock; however, 70,000 copies of this pamphlet circulated across Ireland! The commission even admitted to complicated instructions and stated, "Perhaps you will not succeed very well at first, but we are confident that all true Irishmen will exert themselves..."⁹¹

After only three weeks, the commission's scientists returned to England. Other scientific minds proposed many solutions to the *P. infestans* epidemic. Pamphlets advised Irishmen to soak the potatoes into a mash and eat it with bran and salt; they also suggested treating the potato with chlorine gas to cure the blight. Some suggested baking the potatoes at high enough temperatures to cause the blight to "ooze out of the potato."⁹² Some religious minds suggested that Ireland's "soul" was cursed and that God plagued its farmland.⁹³ Others believed that the disease fell from the sky in raindrops, or the disease came from locomotive smoke, volcanoes, static electricity, or seagull droppings.⁹⁴ As supposed causes and bogus solutions piled up, Irish scientists were working diligently to reverse the damage done by *P. infestans*; however, the reality was, whether boiled, baked, steamed, salted, gassed, ventilated, or treated with chemicals, infected potatoes rotted away into an inedible, unusable heap. Ireland's vital food source was rapidly disappearing,

⁸⁹ O'Neill.

⁹⁰ O'Neill.

⁹¹ United States Patent Office, *Annual Report of the Commissioner of Patents*, 1846.

⁹² Office.

⁹³ Chris Watson, "God and the Great Failure: Poetry from the Irish Famine," *Sydney Studies in Religion* 0, no. 0 (1996), <https://openjournals.library.sydney.edu.au/index.php/SSR/article/view/11993>.

⁹⁴ "The History Place - Irish Potato Famine: The Blight Begins."

and even its most educated minds were powerless to stop it. The alarm turned to terror throughout the country, and by the end of November, the blight had destroyed most crops.

The same strain of fungal *P. infestans* exists in Ireland today, the majority in a latent state, waiting for ideal weather conditions for sporulation. Where this fungus originated is an elusive question, but it most likely arrived in Ireland within a diseased potato unwittingly shipped across the sea from North America.⁹⁵ Today, mitigation for fungal infection includes spraying crops with a specialized copper compound; however, in 1845, scientists were unaware that a fungus could cause blight, let alone that a copper-derived spray could mitigate the pathogen.⁹⁶ The common belief in 1845 was that decomposition brought about fungus, not the other way around. This belief went hand-in-hand with other superstitions and understandably incomplete theories, such as spontaneous generation.⁹⁷

Under a microscope, the fungus consists of numerous long filaments, each having a papilla that holds several zoospores (Figure 6).⁹⁸ The spores germinate to initiate infection. The fungus is dispersed by wind after spores emerge from an infected leaf's stomata under humid conditions. Ireland's weather conditions in 1845 created the perfect conditions for *P. infestans* to flourish.⁹⁹

⁹⁵ Barbara Maranzani, "After 168 Years, Potato Famine Mystery Solved," HISTORY, accessed January 29, 2021, <https://www.history.com/news/after-168-years-potato-famine-mystery-solved>.

⁹⁶ Lars-Wilhelm Bangemann et al., "Copper Reducing Strategies for Late Blight (*Phytophthora Infestans*) Control in Organic Potato (*Solanum Tuberosum*) Production," *Journal of Plant Diseases and Protection* 121, no. 3 (June 1, 2014): 105–16, <https://doi.org/10.1007/BF03356498>.

⁹⁷ Louis Pasteur would not disprove spontaneous generation for another decade. Christina Matta, "Spontaneous Generation and Disease Causation: Anton de Bary's Experiments with *Phytophthora Infestans* and Late Blight of Potato," *Journal of the History of Biology* 43, no. 3 (2010): 459–91.

⁹⁸ "Potato Late Blight," accessed January 29, 2021, <http://archive.bio.ed.ac.uk/jdeacon/microbes/blight.htm>.

⁹⁹ "The Great Irish Potato Blight Of 1845 : The Alabama Weather Blog," accessed March 10, 2021, <https://www.alabamawx.com/?p=178075>.



Figure 6 - *P. infestans*. Papilla (arrowheads) house the numerous spores which will germinate and propagate potato blight.¹⁰⁰

In January 1846, six months after blight initially struck, the people of Ireland began to starve. Farmers begged for whatever work there was. Tenants were unable to pay rent, and mass evictions took place.¹⁰¹ In March 1846, Landlords evicted 300 tenants in one day from a village in Galway; this was known as the Ballinlass incident.¹⁰² Irish (and British) police demolished peasant housing and tore thatched roofs from tenants' homes who could not pay rent. The Ballinlass incident resulted in 76 families being evicted and left with ruins.¹⁰³ (Figure 7 depicts an Irish family being evicted by police, with soldiers on standby.) By June 1846, starvation

¹⁰⁰ "Potato Late Blight,."

¹⁰¹ Tara Leigh Workman, "Famine and Diaspora in the Emerald Isle An Gorta Móhr --The Irish Potato Famine and Its Impact on Irish Migration" (A.M., United States -- New Hampshire, Southern New Hampshire University, 2019), <http://search.proquest.com/docview/2210118130/abstract/D777E7C1631F4C63PQ/1>.

¹⁰² Smith, *The Great Hunger*.

¹⁰³ Janice Holmes, "Problems and Prospects: Reflecting on Irish Local History," *Irish Historical Studies* 40, no. 158 (November 2016): 277–84, <https://doi.org/10.1017/ihs.2016.28>.

affected practically every corner of Ireland. Those who survived looked forward to planting a new summer crop and cultivating new hope. The Irish saying "abundance always follows scarcity" was the mantra of the early half of 1846, and farmers hoped for a reversal of their fortunes.



Figure 7- The Ejectment – *Illustrated London News*, December 16, 1848.¹⁰⁴

Signs pointed to an abundant potato season in the summer of 1846. Early crops showed no signs of *P.infestans* infection. *The Freeman's Journal* declared, "there was every appearance of an abundant harvest."¹⁰⁵ This forecast changed within one week in August. Miles of fields that bloomed with all the luxuriance of sustenance turned to black putrefaction overnight. August 7th, Colonel Knox of County Sligo wrote that every field he encountered was black as if a fire had burned every potato in Ireland.¹⁰⁶ Crop failure was total and absolute. The people of Ireland were

¹⁰⁴ *The Ejectment*, December 16, 1848, Engraving, December 16, 1848, The Illustrated London News.

¹⁰⁵ Smith, *The Great Hunger*.

¹⁰⁶ Smith.

awestruck as their fields had appeared healthy just days earlier. Even a government report asserted, "the crops have never looked better this season."¹⁰⁷

P. infestans can lay dormant for months after infecting a potato, waiting for ideal weather conditions to germinate, proliferate, and infect.¹⁰⁸ Out of desperation, farmers in 1846 had planted the following year's crop with infected potatoes, and the fungus laid dormant throughout the winter, waiting for a perfect humid summer during which to erupt. Irish farmers had no other choice but to plant unknowingly blighted potatoes; it was their only food source, and without it would lead to another year of starvation. During the previous summer of 1845, farmers still had old food stores to fall back on when the potato failed the first time. However, these reserves had been utilized long before the summer of 1846, and desperation ensued.¹⁰⁹ Every item of value, even clothing, was sold to procure provisions. Death from starvation was not probable but an immediate fate for many. *The Times*, having learned of a subsequent crop failure, reported "a total annihilation of Ireland."¹¹⁰

In September of 1846, no vendors were selling goods in Skibbereen, County Cork (an agricultural hub).¹¹¹ Rents had gone unpaid for months, and landlords began evicting their tenants on a massive scale. Starving, homeless mobs began to wander the countryside in search of food and work. On June 13th in Galway, a food riot broke out, resulting in police firing into the gathering crowds, injuring many (Figure 8).¹¹² Even in previously prosperous areas, food was unobtainable. The number of food riots, like the one in Galway, sharply increased over the next several months; there were 27 in September 1846, 181 in December 1846, and 150 in January 1847.¹¹³

¹⁰⁷ Smith.

¹⁰⁸ "Potato Late Blight,."

¹⁰⁹ Smith, *The Great Hunger*.

¹¹⁰ *The Great Irish Famine of 1845-1846: A Collection of Leading Articles, Letters, and Parliamentary and Other Public Statements, Reprinted from the Times*. (London, 1880).

¹¹¹ Kelly, *The Graves Are Walking*.

¹¹² James Kelly, "'Hunger Will Break through a Wall': Food Riots during the Famine," September 21, 2020, <https://www.rte.ie/history/famine-ireland/2020/0921/1166563-hunger-will-break-through-a-wall-food-riots-during-the-famine/>.

¹¹³ Kelly.



Figure 8 – Starving Townspeople Raid a Potato Store in Galway during a Famine
(*London Illustrated News*)¹¹⁴

Historically and prior to the famine, October was the month when most other vegetable stocks typically dwindled, and the Irish diet became primarily potato-based. However, October 1846 would be very different. This time, there was not this failsafe to save the country from starvation.¹¹⁵ In County Cork in November 1846, there were 7,000 people "completely without

¹¹⁴ "Starving Townspeople Raid a Potato Store in Galway during a Famine,... News Photo - Getty Images," accessed March 27, 2021, <https://www.gettyimages.com/detail/news-photo/starving-townspeople-raid-a-potato-store-in-galway-during-a-news-photo/139117429>.

¹¹⁵ Smith, *The Great Hunger*.

food."¹¹⁶ Child mortality rates began to rise, often attributed to "diarrheal disease."¹¹⁷ According to Sir Randolph Routh, Commissary General, there was "a spirit of revolution abroad, and the only way to check it is to have a supply of food."¹¹⁸

As winter progressed and foraged foods such as berries and pine needles dwindled further, an observer, Mr. Forrester, commented:

[the children looked] "like skeletons, their features sharpened with hunger and their limbs wasted. Their happy expressions gone from their faces, leaving an anxious look of premature old age."¹¹⁹

A captain stationed in Ireland wrote the following:

"Though I am a man not easily moved, I confess myself unmanned by the intensity and extent of the suffering I witnessed, more especially among the women and little children, crowds of whom were seen scattered over the turnip fields like a flock of famished crows, devouring the raw turnips, mothers half-naked, shivering in the snow and sleet, uttering exclamations of despair while their children were screaming with hunger. I am a match for anything else I may meet with here, but this I cannot stand."¹²⁰

At this point, nature itself became an enemy of the Irish people. Ireland is known for its mild winters, where potatoes can stay planted throughout the winter months without any risk of loss to frost. However, in 1846, the air turned uncharacteristically cold, and six inches of snow fell upon areas that rarely received any.¹²¹ By January, the snowstorms were heavy and constant.

¹¹⁶ Smith.

¹¹⁷ Christine Kinealy, Jason King, and Gerard Moran, *Children and the Great Hunger in Ireland* (Quinnipiac University Press, 2018).

¹¹⁸ Smith, *The Great Hunger*.

¹¹⁹ *Social Analysis* (Department of Anthropology, University of Adelaide, 1999).

¹²⁰ Captain Wynne, Inspecting Officer, West Clare, Ireland 1846.

¹²¹ "The Great Irish Potato Blight Of 1845 : The Alabama Weather Blog."

Europe documented record snowfall this season.¹²² In starving Ireland, roads became impassable, and the importation and transportation of goods impossible.¹²³ The winter of 1846-1847 exacerbated an already dire situation in Ireland.

In 1847, the workhouses were overcrowded and could not keep everyone who came looking for help. Those admitted receive meager wages. Those evicted from their homes were at the mercy of the harsh weather, and squatters and homeless died by the thousands throughout Ireland. Cork county estimated 100 deaths per week. Thousands gathered at government buildings demanding food subsidies, employment assistance, or any aid. Fear loomed over Ireland as tensions grew and unrest swept throughout the country. As one colonel stated, "there is an undefined notion that something very terrible is going to take place soon."¹²⁴ He was correct. Farmers did not plant the 1847 potato crop. Throughout the growing season, land remained untilled and unsown. A colonel reported seeing only one farmer working his land on a 50-mile journey through the Irish countryside.

Why did farmers fail to cultivate a new crop of potatoes? Starvation plagued the region for two years, leaving farmers too frail to carry out a labor-intensive mission. Due to mass evictions, malnutrition, and disease, farmhands were also scarce. Most importantly, British landowners immediately confiscated any potatoes that did grow (and were unaffected by blight) as backpay for long over-due rent. There were not any viable potatoes available for the next harvest. The House of Commons reported that, as early as 1846, some peasant farmers had eaten their seed potatoes out of desperation.¹²⁵ Sir Charles Edward Trevelyan, the person responsible for administering relief to the impoverished, expressed anti-Irish sentiments. In 1846 he wrote, "The great evil with which we have to contend is not the physical evil of the famine, but the moral evil of the selfish, perverse, and turbulent character of the Irish people."¹²⁶ Remarkably

¹²² Guest Blogger, "Irish Famines, Politics, and Climate History," Watts Up With That?, August 21, 2014, <https://wattsupwiththat.com/2014/08/20/irish-famines-politics-and-climate-history/>.

¹²³ "The Great Irish Potato Blight Of 1845 : The Alabama Weather Blog."

¹²⁴ Smith, *The Great Hunger*.

¹²⁵ Smith.

¹²⁶ "Three Famines — By Thomas Keneally — Book Review - The New York Times." n.d. Accessed February 2, 2021. <https://www.nytimes.com/2011/09/18/books/review/three-famines-by-thomas-keneally-book-review.html>.

few Parliament members stood up for the Irish, but Lord Bernard responded to the anti-Irish sentiment:

"Was it nothing that 16 million pounds worth of food has been lost to the Irish people? Would that not be considered a national calamity if it had happened in England?"¹²⁷

Ireland was indeed in dire straits. It had contended with multiple crop failures, uncharacteristically cold and heavy rains, unplanted fields, a corrupt government, starvation, and civil unrest. Epidemic Louse-Borne Typhus was about to afflict the Irish people.

During the nineteenth century, Ireland suffered *six* typhus epidemics, all connected with some degree of crop failure. Of course, working conditions and sanitation were primitive at the time.¹²⁸ Due to the overwhelmingly vast number of impoverished residents throughout Ireland during 1845-1847, it is not surprising how quickly EL-BT spread throughout the population. Typhus Fever, as alluded to earlier, spreads via the human body louse. Cramped, cold, and dirty conditions—synonymous with impoverished communities—allowed the louse to proliferate and penetrate systemically throughout Ireland in the 1840s. EL-BT is a disease that affects blood vessels and impedes circulation.¹²⁹ Lack of circulation leads to discoloration of the skin; thus, EL-BT was nicknamed by the Irish as "Flabhras Dubh or Black Fever."¹³⁰ Subsequent symptoms include pyrexia, rash, nausea, vomiting, and delirium.¹³¹ Ireland's impoverished simultaneously struggled with relapsing fever, scurvy, and dysentery during the EL-BT epidemic.¹³²

¹²⁷ Great Britain Parliament, *The Parliamentary Debates (Authorized Edition)* (H.M. Stationery Office, 1847). 659

¹²⁸ Patrick Rowan, "The Battle to Get Rid of Irish Typhus," *Irish Medical Times* 43, no. 44 (October 30, 2009): 36–37.

¹²⁹ CDC, "Epidemic Typhus | CDC."

¹³⁰ "Ennistymon Union - Disease," accessed March 10, 2021, <https://www.clarelibrary.ie/eolas/coclare/history/workdisease.htm>.

¹³¹ CDC, "Epidemic Typhus | CDC."

¹³² "Ennistymon Union - Disease."

Nineteenth-century Ireland was an ideal location for an infectious disease like typhus. Cities were devoid of sanitation. Dublin was affectionately nicknamed “Dear Dirty Dublin” by many locals.¹³³ In the rural areas, destitute farmers made lodgings out of mud, which posed various health and sanitation risks. Most dwellings had manure heaps in or just outside the entrance. Some farmers, out of desperation, shared the living space with livestock for shared warmth. Due to the overwhelming number of displaced residents from evictions, families were lying in roadside ditches, gripped with typhus. Typhus eventually was also nicknamed “Roadside Fever.”¹³⁴ Typhus spread quickly in cities where masses gathered to beg or search for work. Public health professionals (doctors, nurses, healers) worked tirelessly to help aid the growing number of infected, risking their own lives in the process.¹³⁵ Ireland was already struggling with a shortage of healthcare workers before the typhus epidemic; now, they were losing what little they did have at an alarming rate.

Although it was known throughout history that disease followed famine, the British government had done little to prepare for the oncoming wave of illnesses that followed the Irish Potato Famine. Public health regulations, agricultural subsidies, infrastructure improvements, emergency services, entitlements, and community assistance were solely Britain's responsibility after their control of Ireland in 1801. In March 1846, during the first season of crop failure, a so-called Fever Bill eventually passed by the British Parliament promised: "...to make temporary provision for the relief of destitute poor persons afflicted with fever in Ireland."¹³⁶ This law founded Ireland's Board of Health, funded hospitals, established triage centers, and assigned British doctors to Ireland. These measures were seemingly a step in the right direction. The flaw in this new law that promised aid to those afflicted with typhus was that it was allowed to expire

¹³³ “Dear, Dirty Dublin - Popular Rhymes and Sayings of Ireland,” accessed March 10, 2021, <https://www.libraryireland.com/social-history/popular-rhymes/dear-dirty-dublin.php>.

¹³⁴ “The HIstory Place - Irish Potato Famine: The Great Hunger,” accessed March 10, 2021, <https://www.historyplace.com/worldhistory/famine/hunger.htm>.

¹³⁵ “Epidemics in Ireland – A Short History – The Irish Story,” accessed March 10, 2021, <https://www.theirishstory.com/2020/03/31/epidemics-in-ireland-a-short-history/>.

¹³⁶ “Fever (Ireland) Bill. (Hansard, 18 March 1846),” accessed April 2, 2021, <https://api.parliament.uk/historic-hansard/commons/1846/mar/18/fever-ireland-bill>.

just six months after enactment.¹³⁷ This expiration meant that the infrastructure designed to help the typhus epidemic preemptively dissolved before the epidemic began. The dissolution occurred in August of 1846 when the new Board of Health (established by the law) was relieved of its duties, and Parliament sent healthcare professionals back to England. The potato crop failed entirely one month later, in September of 1846. Parliament did not reenact any of the dissolved provisions. Four months later, thousands were dying nationally every week without any governmental assistance. Henry Labouchere, the chief secretary, assured the House of Commons that “there was no need to provide additional support.”¹³⁸

Without government support, the rising number of infected patients overburdened the underfunded county fever hospitals. Across the entire country, only 28 hospitals ran at a functioning capacity. One community had no hospital despite having a population of 30,000 within 135 square miles. Makeshift “fever hospitals” were constructed along the countryside to try and alleviate the growing epidemic. Arthur Jacob wrote in the *Dublin Medical Press* in 1847,

“The mud walls of an old cottage eked out with boarding and covered with straw formed Dr. Dunne’s ‘fever hospital’ in which nearly 60 patients were under his treatment at the time he contracted the fever of which he died after a few days.”¹³⁹

Typhus fever was so rampant that it affected all socio-economic classes of the time. The wealthy who took “the fever” had a higher fatality rate than the poor.¹⁴⁰

By early 1847, EL-BT had spread across Ireland, infecting hundreds of thousands across all socio-economic groups. Reports of how rampant the EL-BT epidemic had become caught the attention of government offices. Rural residents migrated into cities in the hope of finding resources but bringing infection with them. Typhus ran rampant in hospitals and workhouses, as

¹³⁷ “Irish Famine Timeline,” accessed April 5, 2021, <https://www.irishhistorian.com/IrishFamineTimeline.html#1846>.

¹³⁸ Smith, *The Great Hunger*. 196

¹³⁹ Peter Froggatt, “Medicine in Ulster in Relation to the Great Famine and ‘the Troubles,’” *British Medical Journal* 319, no. 7225 (December 18, 1999): 1636–39. 1636

¹⁴⁰ John B White, “Infection In A Village Community In The 19th Century And The Development Of The Dispensary System,” *The Ulster Medical Journal* 77, no. 3 (September 2008): 153–59.

well as army bases, ports, and prisons. According to the report of the Poor Law Commission in December 1846,

“In Connacht and the south of Ireland such has been the frightful state of distress that the workhouses were crowded to an extent far beyond their calculated capacity and disease has been introduced by persons suffering under dysentery and fever, and has spread to the inmates and officers who were previously healthy ... In the present state of things nearly every person admitted is a patient; separation of the sick by reasons of their number becomes impossible; disease spreads, and by rapid transmission, the workhouse is changed into one large hospital.”¹⁴¹

Mass graves appeared in several counties across the country. The epidemic was so burdensome that parents would abandon their children in the countryside after learning they contracted EL-BT. Due to typhus’s ability to be aerosolized, those who aided the victims—clergy, nuns, physicians, landlords, and government officials—often contracted typhus and died, though they may never have harbored a louse.¹⁴² In 1847 this death from “fever” accounted for 4% of all physicians, surgeons, and apothecaries in Ireland.¹⁴³ Table 1 depicts the number of medical professionals who died in Ireland, by disease, in 1847.¹⁴⁴ The table shows that 69% of deaths among medical professionals were attributed to epidemic and contagious fevers during 1847.

¹⁴¹ Helene O’Keeffe, “How the Temporary Fever Act Failed to Stop Epidemics,” January 28, 2021, <https://www.rte.ie/history/famine-ireland/2021/0128/1193691-how-the-temporary-fever-act-failed-to-stop-an-epidemic/>.

¹⁴² Smith, *The Great Hunger*.

¹⁴³ Froggatt, “Medicine in Ulster in Relation to the Great Famine and ‘the Troubles.’”

¹⁴⁴ Froggatt.

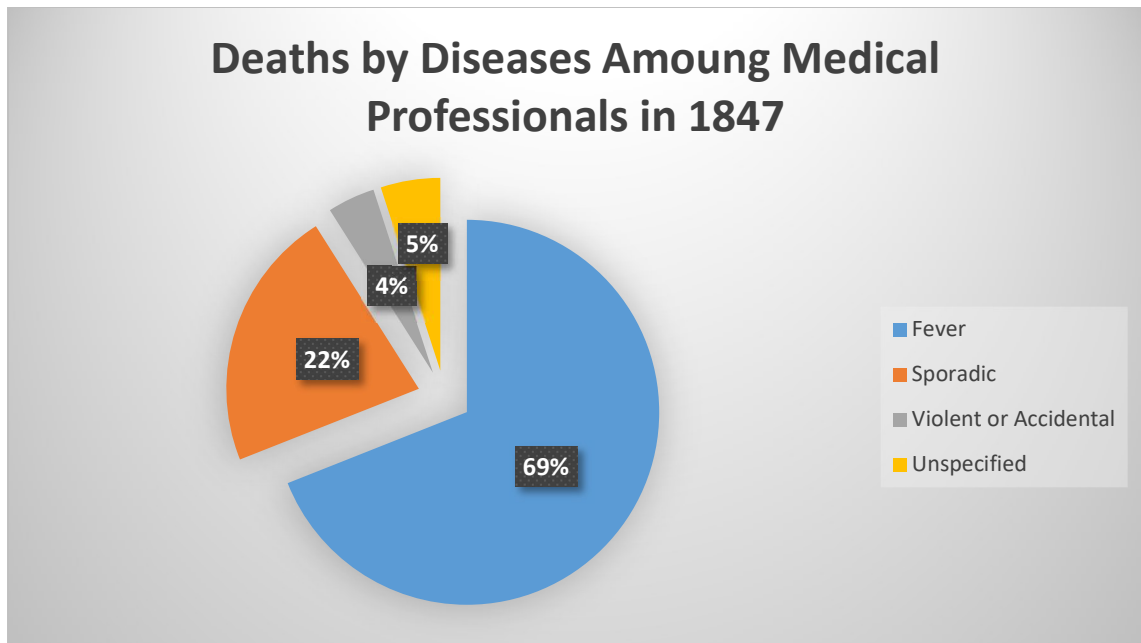


Figure 9—Numbers of medical professionals who died in Ireland, by disease, in 1847.¹⁴⁵

By March 1847, the government passed a new law, the Temporary Relief Act, allotted funding for hospitals, doctors, medicine, and food subsidies. Ireland's lack of infrastructure and unresponsive system of government made the distribution of aid somewhat problematic. The commissioners' board refused to spend money to build a new fever hospital in one county despite the new law. Instead of building new medical infrastructure, some municipalities set up army-style tents to house the sick.

Although aid was available in other areas, many could not gain access to it. One doctor estimated that for every peasant that sought aid, there were 4-5 that did not. Lack of confidence in the Irish healthcare infrastructure was very high, and many peasants were afraid of the fever hospitals as they were overcrowded, and many saw the high mortality rates in these facilities as bad omens.

Over time, the Temporary Relief Act was considered a success. Parliament built upon the sanitation infrastructure throughout Ireland. Sanitation workers cleaned streets, established drainage systems, and buried the dead safely. The bill also established new accommodations for

¹⁴⁵ Data presented in graphical format by the thesis author; original data from Froggatt.

23,000 patients and hired numerous doctors and nurses to meet the demand. The epidemic was still proving to be detrimental to Ireland, but governmental aid slowly alleviated the burden.

There is no accurate record of the mortality rate of EL-BT in Ireland in the 1840s. The government did not keep an official record, census, or legal register of deaths. Due to low confidence in Parliament, peasants refused to cooperate with appointed statisticians and census workers. The precise death toll can never entirely be determined; historical epidemiologists estimate that 800,000 people died between the fall of 1846 and the spring of 1851, accounting for almost a tenth of the population at the time.¹⁴⁶ A memorial erected in Ireland describes the atrocities as “Britain’s Genocide by Starvation” (Figure 10) and cites the total number of estimated deaths.



Figure 10 - "An Gorta Mór, Britain's genocide by starvation, Ireland's Holocaust 1845–1849." Modern Irish famine mural in Belfast.

¹⁴⁶ S. H. Cousens, "The Regional Variation in Mortality during the Great Irish Famine," *Proceedings of the Royal Irish Academy. Section C: Archaeology, Celtic Studies, History, Linguistics, Literature* 63 (1962): 127–49.

The Irish working class witnessed the failure of their country's infrastructure and many abandoned homes. Staying in Ireland meant impending death, disease, starvation, and homelessness. There was little viable farmland due to *P. infestans*, little work due to overcrowded workhouses, no accommodations due to mass evictions, and no salvation from the rapidly spreading EL-BT epidemic. Many turned to the only remaining option: emigration.

The Irish fled their homes on “long cónra” or “coffin ships.”¹⁴⁷ Historical epidemiologists refer to coffin ships as any ships that carried Irish immigrants fleeing the Irish Potato Famine. These ships were crowded, unsanitary, and deadly. The average mortality rate on coffin ship voyages was 30%.¹⁴⁸ Coffin ships, and their infected passengers, were catalysts of a global public health event: the 1847 North American Typhus Epidemic in Canada and the United States. In Canada, more than 20,000 people died in 1847-1848. An influx of Irish immigrants to New York resulted in a typhus outbreak in 1847, with 80% of the cases contracted during the Atlantic crossing and 20% of the cases resulting from a secondary spread. The mortality rate was 11%.¹⁴⁹ First-hand accounts recall that sharks followed the ships due to the overwhelming number of bodies thrown overboard.¹⁵⁰ This Irish diaspora brought, to North America, hundreds of thousands of ill, starved, unskilled peasants searching to escape their homeland atrocities. In the decade in which the famine occurred, 1.3 million people emigrated overseas.¹⁵¹ 70% went to the USA, 28% to Canada, and 2% to Australia.¹⁵²

Analysis and Cause-Effect Relationships

¹⁴⁷ Smith, *The Great Hunger*.

¹⁴⁸ “On Board the Dunbrody Famine Ship | Coffin Ships | The Voyage |,” *Dunbrody Famine Ship and Irish Emigrant Experience* (blog), accessed March 9, 2021, <https://www.dunbrody.com/visitor-info/irish-emigrant-experience/the-voyage/>.

¹⁴⁹ Gelston and Jones, “Typhus Fever.”

¹⁵⁰ D. J. Hickey, D. J. Hickey, and J. E. Doherty, *A Dictionary of Irish History Since 1800* (Gill and Macmillan, 1980).

¹⁵¹ Donald H. Akenson and Queen's University of Belfast Institute of Irish Studies, *The Irish Diaspora: A Primer* (P.D. Meany, 1993).

¹⁵² *Union to Partition: Ireland 1800-1921* (Colourpoint Books, 2006).

True to the research methodology outlined in chapter 1, this section addresses two objectives: (1) identifying cause-effect relationships between social and economic factors and the Irish Potato Famine-related EL-BT event, and (2) identifying cause-effect relationships between expressly biological factors and the event. Examining the causal influence of biological (pathogen, host, environment) and socio-economic factors involves an admittedly inductive read of the historical record; however, this exercise is worthwhile for both confirming what the literature has established (see Chapter 1) and, quite possibly, identifying new insights into the pathology and sociology of typhus.

Ireland was subject to several pivotal events that led to the Irish Potato Famine and the subsequent EL-BT outbreak. Both social and economic factors contributed to the susceptibility to both the famine and subsequent EL-BT outbreak events. Table 1 summarizes some of the direct and indirect causes of Ireland's crop failure. Admittedly, these cause-effect observations are *not* expressly related to EL-BT; however, they relate to the ultimate EL-BT events described in this chapter.

Table 1 — Causes of Irish Potato Crop Failure

Cause	Effect
Increased Rent and Slumlord Land Management	Increase population density in housing and overcrowded living conditions
Population Growth	Increased food insecurity and population density
Potato Blight affected Irish Potato Crop	Devastates almost entire potato harvest leading to mass starvation
Uncharacteristic Weather Patterns	Prevents subsequent crops from being planted—proliferating the famine/poverty cycle.

Ultimately, the famine contributed to massive poverty. This poverty forced thousands into unsanitary conditions, which allowed for the proliferation of body lice. This infestation led to an outbreak of EL-BT. We can attribute the causality of EL-BT to poverty (a socio-economic factor), homelessness (a socio-economic factor), unsanitary conditions (both a socio-economic and biological factor), famine (a biological factor), and body lice infestation (a biological factor).

Tables 2 and 3 outline the socio-economic and biological factors that contributed to the EL-BT outbreak in Ireland.

Table 2 — Socio-Economic Factors that Contributed to the EL-BT Outbreak in Ireland.

Socio-Economic Factor	Effect
Poverty	<ul style="list-style-type: none"> • Prolonged exposure to lice-infected clothing due to the inability to purchase multiple sets • Prevents proper treatment options
Homelessness	<ul style="list-style-type: none"> • Increased mass gatherings in public housing • Allowed the direct transfer of lice and aerosolized transfer of infected lice fecal matter
Unsanitary Conditions	<ul style="list-style-type: none"> • Allows uninhibited lice proliferation

Table 3 — Biological Factors and Their Effects that Contributed to EL-BT Outbreak in Ireland.

Biological Factor	Effect
Unsanitary Conditions	Allows uninhibited lice proliferation
Body Lice Infestation	Facilitated transmission of EL-BT
Famine	Weakened immune status of infected

The EL-BT outbreak was caused by poverty, homelessness, unsanitary conditions, famine, and the proliferation of *R. prowazekii* vectors (i.e., lice). Of the five factors, it can be said that body lice infestation was the most proximal (direct) cause. However, the infestation itself was caused or exacerbated by the other four factors. Poverty increased mass gatherings, allowing for the direct transmission of infected lice or aerosolized transmission of fecal matter. The Centers for Disease Control and Prevention (CDC) recommends avoiding overcrowded areas to prevent epidemic typhus.¹⁵³ Poverty also prevented extra sets of clean clothes from

¹⁵³ CDC, “Epidemic Typhus | CDC.”

being bought and proper avenues of treatment from being explored. Homelessness caused peasants to wear multiple layers of clothing during the winter. The added warmth allowed the lice to remain alive within the inner layers of clothing and continue to infect throughout the winter. Unsanitary conditions involve the loss of standard hygiene practices (i.e., showering, laundry, sanitation of living spaces, and proper disposal of the deceased). The CDC recommends showering and laundering as mitigation strategies to prevent epidemic typhus.¹⁵⁴ Famine weakens the body and immune system and prevents mitigation strategies from being executed.¹⁵⁵

¹⁵⁴ CDC.

¹⁵⁵ Claire D. Bourke, James A. Berkley, and Andrew J. Prendergast, “Immune Dysfunction as a Cause and Consequence of Malnutrition,” *Trends in Immunology* 37, no. 6 (June 2016): 386–98, <https://doi.org/10.1016/j.it.2016.04.003>.

Chapter 3 - *Rickettsia prowazekii* and Contemporary EL-BT Events

Recent Historical Contexts

EL-BT is one of humanity's most enduring pestilential diseases. As explained in Chapter 1, the etiologic agent of EL-BT is *R. prowazekii*. It is a type of endogenous bacteria found in the human body louse (*Pediculus humanus corporis*). The emergence of infectious typhus outbreaks usually accompany rapid population migration, inadequate sanitation, and starvation in general; Chapter 2 detailed one such scenario in 19th-century Ireland. In the last 150 years, battles and military conflict (as well as famine situations) have been associated with EL-BT outbreaks. Fortunately, EL-BT today is considered a relatively rare public health problem; however, it should not be overlooked in light of today's rapidly rising and global demographic patterns. Table 4 illustrates the historical EL-BT events resulting from war from the early 19th century until as recently as 1997. Historically, large suspected outbreaks of epidemic typhus occurred worldwide, especially among military troops during the Napoleonic Wars and the first and second World Wars. Epidemic typhus was widespread globally before the introduction of modern antibiotics. Outbreaks of louse-borne Typhus occur during the colder months from overcrowding, and during times of war, it is due to overcrowding and unsanitary conditions prevalent during times of conflict.¹⁵⁶

¹⁵⁶ “Arthropod-Borne Diseases Associated with Political and Social Disorder | Annual Review of Entomology.”

Table 4 — Notable Typhus Epidemics Throughout History ¹⁵⁷

Period	Outbreak	Other Possible Disease (in addition to EL-BT)
1812	Napoleonic Wars (Vilnius, Eastern Europe)	Trench Fever
1914-18	World War 1 (Russia, Europe)	Trench Fever
1917-25	Bolshevik Revolution (Russia)	Other louse-borne diseases
1940-45	World War II (Europe, North Africa)	Trench Fever
1997	Burundi Civil War (Central Africa)	Trench Fever

Pathobiology and Recent EL-BT Disease Events

Transmission

Body Lice Infestation

As a result of conflict and warfare, or due to increased population density and size, urbanization, and chronic poverty, more impoverished parts of the population live in congested conditions, ideal for developing ectoparasites like lice.¹⁵⁸ There are thousands of different types of lice, but only three of them harm humans: the head louse (*Pediculus humanus capitis*), the body louse (*pediculus humanis corporis*), and pubic louse (*pediculus humanus pubis*).¹⁵⁹ The body louse is associated more frequently with substandard hygiene and poverty. When people

¹⁵⁷ Table adapted from Microbiology Society, “Typhus in World War I,” accessed March 26, 2021, <https://microbiologysociety.org/publication/past-issues/world-war-i/article/typhus-in-world-war-i.html>.

¹⁵⁸ “Arthropod-Borne Diseases Associated with Political and Social Disorder | Annual Review of Entomology.”

¹⁵⁹ CDC-Centers for Disease Control and Prevention, “CDC - Lice,” January 11, 2021, <https://www.cdc.gov/parasites/lice/index.html>.

began to wear clothing, the human body louse might have evolved from a common ancestor of the head louse.¹⁶⁰ One theory for the origin of body lice is that individuals with poor hygiene and head louse infection allowed head louse variations capable of ingesting a bigger blood meal (a feature of body lice) to inhabit clothes.¹⁶¹

Louse transmission is closely linked to close body-to-body contact. As a result, infestations are more common in crowded places like homeless shelters, refugee camps, and jails, mainly when sanitary standards are inadequate.¹⁶² The body lice have only one natural enemy, its host.¹⁶³

The life cycle of a body louse begins with an egg deposited in the folds of clothing. The eggs are frequently attached to inner clothes, near the skin, when the body temperature exceeds 29°C-32°C because the body louse is particularly vulnerable to cold. The inside belts of undergarments, slacks, and skirts are the best places to search for lice or eggs. The female's auxiliary gland produces an adhesive that keeps the eggs in place.¹⁶⁴ The eggs hatch 6-9 days after being laid when kept at a steady temperature (i.e., when clothing is not removed). The newly emerged louse feeds on the skin before retreating to the clothes, where it will remain until it feeds again. A louse feeds five times each day on average. The developing louse molts three times after hatching, generally on days 3, 5, and 10. The adult louse usually lives for another 20 days after the last molt. The blood meal is quickly digested. Erythrocytes are hemolyzed fast and remain aqueous. When lice reach adulthood, they may mate right away, and both the male and

¹⁶⁰ “Molecular Evolution of *Pediculus Humanus* and the Origin of Clothing - ScienceDirect,” accessed July 21, 2021, <https://www.sciencedirect-com.er.lib.k-state.edu/science/article/pii/S0960982204009856?via%3Dihub>.

¹⁶¹ Wenjun Li et al., “Genotyping of Human Lice Suggests Multiple Emergences of Body Lice from Local Head Louse Populations: E641,” *PLoS Neglected Tropical Diseases* 4, no. 3 (March 2010): e641, <http://dx.doi.org.er.lib.k-state.edu/10.1371/journal.pntd.0000641>.

¹⁶² “Arthropod-Borne Diseases Associated with Political and Social Disorder | Annual Review of Entomology.”

¹⁶³ Ian F. Burgess, “Human Lice and Their Management,” in *Advances in Parasitology*, ed. J. R. Baker, R. Muller, and D. Rollinson, vol. 36 (Academic Press, 1995), 271–342, [https://doi.org/10.1016/S0065-308X\(08\)60493-5](https://doi.org/10.1016/S0065-308X(08)60493-5).

¹⁶⁴ J. W. Maunder, “The Appreciation of Lice,” *Proceedings of the Royal Institution of Great Britain* 55 (1983): 1.

female continue to feed during the lengthy mating process.¹⁶⁵ Females lay eight eggs each day on average. Daily mating is required because they lack a spermatheca for storing sperm, and females must mate before producing eggs. The population density varies. Typically, only a few lice are seen on a single host; however, some afflicted individuals have been seen with over 300 lice!¹⁶⁶ During their one-month lifespan, a couple of mating lice may theoretically produce 200 lice.¹⁶⁷

For lice, which are prone to dehydration, humidity is a critical element for survival.¹⁶⁸ They can survive if the humidity level is between 70 and 90 percent; if it drops below 40 percent, they cannot survive.¹⁶⁹ In contrast, when the humidity is excessively high, louse feces become sticky and cling to clothing, killing the lice. The louse's only way to stay hydrated is to eat blood. The narrow diameter of the proboscis hinders fast blood uptake, necessitating frequent, smaller meals.¹⁷⁰ Temperature also influences the physiology of the louse. The lice will flee if the host becomes too hot due to a fever or strenuous exercise. Although eggs may live at colder temperatures than adults, their lifespan is limited to 16 days.¹⁷¹

The human body louse is the primary vector of person-to-person transmission of EL-BT. When lice feed on the blood of infected patients, they get infected; when they feed on a new host, they defecate, excreting *R. prowazekii* in the feces. Transmission occurs when the host scratches or rubs bacteria from the louse excrement or crushed lice into bite marks or other breaches in the skin. For lice, *R. prowazekii* is fatal, and infection results in death within three weeks.¹⁷²

¹⁶⁵ Maunder.

¹⁶⁶ Cedric Foucault, Philippe Brouqui, and Didier Raoult, "Bartonella Quintana Characteristics and Clinical Management," *Emerging Infectious Diseases* 12, no. 2 (February 2006): 217+.

¹⁶⁷ Francis C. Evans and Frederick E. Smith, "The Intrinsic Rate of Natural Increase for the Human Louse, *Pediculus Humanus* L.," *The American Naturalist* 86, no. 830 (1952): 299–310.

¹⁶⁸ Burgess, "Human Lice and Their Management."

¹⁶⁹ Maunder, "The Appreciation of Lice."

¹⁷⁰ Burgess, "Human Lice and Their Management."

¹⁷¹ "Arthropod-Borne Diseases Associated with Political and Social Disorder | Annual Review of Entomology."

¹⁷² "Department of Agriculture | Typhus Fever - *Rickettsia Prowazekii*," accessed June 25, 2021, <https://www.nj.gov/agriculture/divisions/ah/diseases/typhus.html>.

Inhalation

Inhalation or contact with the mouth's and eye's mucous membranes can also spread *R. prowazekii* from person to person. When infected body louse feces are deposited in clothes and subsequently disturbed, aerosol transmission can occur; this has also been proven in the laboratory.¹⁷³ *Rickettsia prowazekii* is classified as a possible bioterrorism agent due to its high morbidity and mortality, simplicity of manufacturing and transmission, and potential for aerosol dispersion.¹⁷⁴ The World Health Organization predicts that after a hypothetical air deployment of 50 kg of typhus agent, 104,000 casualties, 19,000 deaths, and 85,000 incapacitated.¹⁷⁵

Poverty

Epidemic typhus caused by *R. prowazekii* is associated with louse infestation and poverty. Persecution, conflict, violence, human rights violations, or incidents that significantly disrupt public order displaced 82.4 million people globally by the end of 2020.¹⁷⁶ Migrants and asylum seekers in industrialized nations face similar living circumstances to those seen in refugee camps or prisons during times of conflict.¹⁷⁷ According to UN-Habitat, 1.6 billion people worldwide live in substandard housing, with around 15 million forcibly evicted each year.¹⁷⁸ Domestically, homelessness affected 567,715 persons in the United States in 2019.¹⁷⁹

¹⁷³ “*Rickettsia Prowazekii* (Epidemic Typhus),” Johns Hopkins Center for Health Security, accessed July 26, 2021, <https://www.centerforhealthsecurity.org/our-work/publications/epidemic-typhus-fact-sheet>.

¹⁷⁴ Azad, “Pathogenic *Rickettsiae* as Bioterrorism Agents.”

¹⁷⁵ Daryl J. Kelly et al., “The Past and Present Threat of *Rickettsial* Diseases to Military Medicine and International Public Health,” *Clinical Infectious Diseases* 34 (2002): S145–69.

¹⁷⁶ United Nations High Commissioner for Refugees, “UNHCR - Refugee Statistics,” UNHCR, accessed June 17, 2021, <https://www.unhcr.org/refugee-statistics/>.

¹⁷⁷ “Arthropod-Borne Diseases Associated with Political and Social Disorder | Annual Review of Entomology.”

¹⁷⁸ “First-Ever United Nations Resolution on Homelessness | DISD,” accessed June 17, 2021, <https://www.un.org/development/desa/dspd/2020/03/resolution-homelessness/>.

¹⁷⁹ “State of Homelessness: 2020 Edition,” National Alliance to End Homelessness, accessed June 17, 2021, <https://endhomelessness.org/homelessness-in-america/homelessness-statistics/state-of-homelessness-2020/>.

Diagnosis

Contemporary diagnosis of rickettsial infection uses indirect fluorescent antibody testing to identify a particular antibody. Serological cross-reaction occurs between bacteria that are closely related. As a result, a cross-adsorption assay that allows removal of the cross-reacting antibody is required to validate the species.¹⁸⁰ Researchers also use polymerase chain reaction (PCR) as a validation method to confirm rickettsial infections.

Clinical Features

After infestation of the infected body louse, the incubation period of EL-BT within the human body is typically between 10 and 14 days. The symptoms are associated with infections of endothelial cells and the subsequent rickettsia-induced vasculitis. Symptoms (relative frequency given in brackets) include high fever (100%), headache (91–100%), rapid and shallow breathing (97%), chills (82%), and muscle soreness and fatigue (70%), the latter being generally intense.¹⁸¹ The onset of a rash is frequent, and this clinical feature is noteworthy for supporting the diagnosis. The rash starts in the shoulders and armpits, primarily spreads over the abdomen, and may extend centrifugally towards extremities (generally sparing the face, palms, and soles). Lesions initially appear non-patterned, with erythematous and blanching areas, but later as petechial and even purpuric lesions, often attributed to vasculitis (in around one-third of patients).¹⁸²

Mitigation

Prophylaxis Treatment

Although a complete change of clothing is the most straightforward approach for delousing, it is not always possible or even practical. Other easy solutions, such as washing garments in water at least 60 °C, can be helpful. Another option is to powder dust all garments

¹⁸⁰ B La Scola and D Raoult, “Laboratory Diagnosis of Rickettsioses: Current Approaches to Diagnosis of Old and New Rickettsial Diseases,” *Journal of Clinical Microbiology* 35, no. 11 (November 1, 1997): 2715–27, <https://doi.org/10.1128/jcm.35.11.2715-2727.1997>.

¹⁸¹ Bechah et al., “Epidemic Typhus.”

¹⁸² Bechah et al.

with 10% DDT, 1% malathion, or 1% permethrin dust. Other than recently used blankets or clothing, there is no need to sterilize other belongings.¹⁸³ Controlling pests may be difficult, especially within homeless populations. Regular inspections, cleanliness measures, continuous maintenance, and population education all help mitigate the risk. Public health programs should engage rapidly to eliminate pests and limit the prevalence of arthropod-borne diseases; early detection can slow the proliferation of infestation in populations, decreasing the risk of latent cases prolonging outbreak duration.

Therapeutic Treatment

Antibiotic and antiparasitic administration mitigate the risk of body lice infections and subsequent EL-BT infections. Doxycycline (single dose 200mg orally) is used as a treatment option in some cases. Although the effect of ivermectin in eradicating the human body louse is not long-lasting, it may provide an alternative treatment method. As underlined in existing CDC guidelines for managing and preventing louse-borne illnesses, the best control approach for typhus is delousing coupled with antibiotic therapy.¹⁸⁴

Contemporary Outbreaks

Between the 1950s and 1980s, significant epidemics of EL-BT became less frequent, and its geographical distribution declined in areas where living standards improved.¹⁸⁵ During the 1990s, louse-borne typhus re-emerged; these events were associated with poor sanitary conditions (such as in prisons and refugee camps) and colder climates found in mountainous regions. Researchers also discovered louse-borne illnesses in Rwandan prisons and Burundi refugee camps in 1993.¹⁸⁶ These EL-BT incidents have occurred in rural and urban areas in developed and developing countries and predominantly among homeless populations.¹⁸⁷ Three

¹⁸³ Raoult and Roux, “The Body Louse as a Vector of Reemerging Human Diseases.”

¹⁸⁴ CDC, “Epidemic Typhus | CDC.”

¹⁸⁵ “Epidemic Typhus Associated with Flying Squirrels -- United States.”

¹⁸⁶ Raoult et al., “Outbreak of Epidemic Typhus Associated with Trench Fever in Burundi.”

¹⁸⁷ “Arthropod-Borne Diseases Associated with Political and Social Disorder | Annual Review of Entomology.”

EL-BT events in recent history are worthy of investigation for the influence of biological and socio-economic factors. These events will now be introduced and analyzed.

EL-BT Outbreak Linked to the Burundian Civil War

Burundi is a nation located in east-central Africa. Burundi's Hutu people, who are historically farmers, make up the great bulk of the country's population. The Tutsi minority, on the other hand, has long held sway over the army and controlled the majority of the economy, notably the lucrative international coffee trade.¹⁸⁸ A civil war ravaged the country after Melchior Ndadaye, the first democratically elected president, was assassinated in 1993.¹⁸⁹ The Burundian Civil War lasted from 1993 to 2005. An outbreak of EL-BT was associated with a jail in Ngozi, the capital of Burundi, in 1995.¹⁹⁰ The EL-BT outbreak, linked to body louse infestations, spread across the country's higher-altitude and colder areas until 1997. Field studies obtained serum samples and removed infected body lice from refugees in 1997. The microbiological analysis included antibody estimates and specific PCRs aimed at the validation of EL-BT. Testing found *R. prowazekii* in 75% of the patients. As of September 1997, Burundi clinically identified a total of 45,558 cases of EL-BT. After a single dose of 200mg doxycycline was given to suspected patients, the mortality rate among prison inmates dropped from 15% to 0.5 %.

EL-BT Outbreak Linked to Ethiopian Famine Crisis

The second noteworthy event took place in Ethiopia, a decade before Burundi's EL-BT event. Civil war and recurrent drought lead to crop failures in drought-prone northern Ethiopia. Ethiopia's food shortages and hunger crises between 1983 and 1985 resulted in 1.2 million fatalities. Four hundred thousand refugees and 2.5 million individuals were in some way displaced from their homes.¹⁹¹ Similar to the famine in Ireland, EL-BT came on the heels of

¹⁸⁸ "Burundi | History, Geography, & Culture | Britannica," accessed July 26, 2021, <https://www.britannica.com/place/Burundi>.

¹⁸⁹ "Burundi - History | Britannica," accessed July 26, 2021, <https://www.britannica.com/place/Burundi/History>.

¹⁹⁰ Raoult et al., "Outbreak of Epidemic Typhus Associated with Trench Fever in Burundi."

¹⁹¹ Peter Gill, "Famine and Foreigners: Ethiopia since Live Aid," n.d., 297.

starvation events across the country. During the famine years, 14,078 cases of EL-BT were reported. In 1984, Ethiopia reported a case-fatality rate of 3.8%, which one author argues is low compared to other outbreaks among untreated populations. Diagnostics for validation included antibody estimates. Treatment included a variety of antibiotics administered depending on the most probable cause of fever at the time of admittance.¹⁹²

EL-BT Outbreaks in Mexico linked to Chronic Body Lice Infestation

The third case happened shortly over a half-century ago. EL-BT has long been a problem in Mexico. In 1951, a countrywide effort against louse-borne typhus was launched; this involved newly discovered technological methods, medicines, and pesticides, which resulted in lower incidence and case-fatality rates. EL-BT claimed the lives of 737 people in 18 states; a public health disaster ensued, and 6,781 communities were classified as being in danger. By 1965, only 36 instances had been documented, with no deaths, from 12 states and 4,841 communities. In 1979, it had been ten years since any cases of epidemic typhus had been recorded in Mexico. Three typhus epidemics occurred in rural areas in the 1980s, two in Chiapas and one in Mexico State. EL-BT events happened less frequently in the 1990s as public health response improved. The numbers of cases of EL-BT reflect the prevalence of lice infestation in indigenous populations. The incidence of lice infestation was 100% in the early 1980s, 58% in 1988, and 15% in 1990.¹⁹³

Analysis and Cause-Effect Relationships

As witnessed in Chapter 2's analysis of the Irish famine and EL-BT events, five socio-economic and biological factors have historically contributed to EL-BT outbreaks. These include poverty (a socio-economic factor), homelessness (a socio-economic factor), unsanitary conditions (both a socio-economic and biological factor), famine (a biological factor), and body lice infestation (a biological factor). Each of the three contemporary-era outbreak events

¹⁹² Perine et al., "A Clinico-Epidemiological Study of Epidemic Typhus in Africa."

¹⁹³ Virginia E. Alcantara et al., "Typhus Group Rickettsiae Antibodies in Rural Mexico," *Emerging Infectious Diseases* 10, no. 3 (March 2004): 549–51, <https://doi.org/10.3201/eid1003.030438>.

described above also signal the operation of one or more of the five factors as a cause of the EL-BT event.

Table 5 outlines the factors (both socio-economic and biological) that demonstrably contributed to the EL-BT outbreak linked to the Burundian Civil War. The conflict led to an increase in jail and refugee populations. These camps were overcrowded and lacked proper sanitation, thus allowing lice proliferation to spread throughout these populations.

Table 5— Factors Contributing to the EL-BT Outbreak Linked to the Burundian Civil War

Factor	Factor Type (Socio-Economic or Biological)	Effect
Unsanitary Conditions	Socio-economic Biological	Allows uninhibited lice proliferation
Body Lice Infestation	Biological	Facilitated transmission of EL-BT

Table 6 outlines the factors that clearly caused the EL-BT outbreak during the Ethiopian famine years. Like the famine in Ireland, crop failures led to mass starvation, homelessness, and poverty. The impoverished, living in unsanitary conditions, eventually succumbed to body lice infestations, leading to the EL-BT event.

Table 6 — Factors Contributing to the EL-BT Outbreak Linked to the Ethiopian Famine Crisis

Factor	Factor Type (Socio-Economic or Biological)	Effect
Famine	Biological	Weakened immune status of infected
Homelessness	Socio-economic	Increased mass gatherings in public housing Allowed the direct transfer of lice and aerosolized transfer of infected lice fecal matter
Poverty	Socio-economic	Prolonged exposure to lice-infected clothing due to the inability to purchase multiple sets Prevents proper treatment options
Unsanitary Conditions	Socio-economic Biological	Allows uninhibited lice proliferation
Body Lice Infestation	Biological	Facilitated transmission of EL-BT

Table 7 outlines the factors that contributed to the EL-BT events in Mexico from 1951-1990. These events were principally caused by chronic lice infestation in multiple Mexican states. Body lice flourished within indigenous populations, especially before proper mitigation strategies were adopted. Since bathing and washing of garments is considered an effective mitigation strategy, it can be assumed that these practices were not being utilized before the country-wide effort was launched.

Table 7 — Factors that contributed to EL-BT Outbreaks in Mexico linked to Chronic Body Lice Infestation

Factor	Factor Type (Socio-Economic or Biological)	Effect
Unsanitary Conditions	Socio-economic Biological	Allows uninhibited lice proliferation
Body Lice Infestation	Biological	Facilitated transmission of EL-BT

These three events show how EL-BT can be caused by the previously outlined five factors: poverty, homelessness, unsanitary conditions, famine, and lice proliferation. The next chapter in this thesis will discuss public health professionals can meaningfully and strategically respond in light of the five factors' influence.

Chapter 4 - Conclusion

As explained in Chapter 1, this thesis had two concrete objectives: (1) identifying cause-effect relationships between social and economic factors and outbreak events, and (2) identifying cause-effect relationships between expressly biological (pathogen, host, and environment) factors and outbreak events. As identified and analyzed in Chapters 2 and 3, five socio-economic and biological factors have caused past EL-BT outbreak events. These factors include poverty (a socio-economic factor), homelessness (a socio-economic factor), unsanitary conditions (both a socio-economic and biological factor), famine (a biological factor), and body lice infestation (a biological factor).

The presence of one or more of the five variables as a cause of the EL-BT event is likewise signaled by each of the four outbreak occurrences mentioned above. Crop failures created a countrywide famine in 19th-century Ireland, resulting in homeless and impoverished thousands of people. Body lice thrived in the filthy circumstances of workhouses and shelters, spreading *R.prowazekii* throughout the population. The socioeconomic upheaval produced by Burundi's civil war (1993-1997) increased the number of people living in refugee camps and jails. The unsanitary conditions in these facilities resulted in an unrestricted body lice infestation that spread pathogenic *R.prowazekii* across these populations. Like in 19th-century Ireland, crop failure in Ethiopia during the 1980s resulted in a countrywide famine, causing people to become homeless and impoverished. Because of the rise in homelessness, many people found themselves in overcrowded shelters with poor sanitation, which allowed infective lice to spread EL-BT. Due to a lack of sanitary mitigation, lice infestations went unchecked during several recent decades in Mexico, spreading EL-BT to numerous states. Together, the five factors had a causal influence on the propagation of EL-BT in the four cases.

Public health practitioners (i.e., epidemiologists, physicians, public health educators, etc.) should not let EL-BT's rarity inhibit diligence for epidemic readiness. Socio-political disorder can continue to affect millions around the world. With climate changing, crops can continue to fail. With the global population ever-rising, starvation is a constant threat worldwide. These events can act as catalysts for famine, poverty, homelessness, unsanitary conditions, and lice proliferation. To prevent building a significant reservoir of latent infection for future epidemics

emerging from recrudescence typhus in louse-infested populations, global health leaders should focus on monitoring, risk assessment, diagnostic capacity, and preparation for fast epidemic control. Global policymakers (i.e., politicians, World Health Organization leaders, parliamentary officials, etc.) should encourage global disease surveillance and promote reporting of disease events to allow rapid intervention. Humanitarian activists and the international community should learn from past; the late summer 2021 war-torn problems in Afghanistan (related with the Taliban's comeback) are creating conditions for EL-BT, as indicated by the variables described in this thesis.¹⁹⁴

The author and her advisor are encouraged by a recent June 2021 Congressional Research Service report that the US is prioritizing global health during the transition from the Trump to the Biden presidential administrations.¹⁹⁵ Nearly \$1.0 billion has been requested for global health security in FY2022. The money will be used to extend the Global Health Security Agenda (GHSA), detect and respond to zoonotic risks, and improve laboratory and surveillance capabilities. Many global health professionals believe that investments in health systems can help the world prepare for the next infectious disease danger in addition to infectious disease response. Assurance that funds are allocated and used effectively and adequately is imperative to improve global disease surveillance and outbreak prevention.

Any such funding and policy initiatives ought to address the five factors identified in this thesis; however, they were found to be causes of EL-BT events. In particular, the five factors are arguably important determinants in other infectious disease outbreaks. Therefore, any new global health policy agenda should strategically address (perhaps through other policy budgets and programs) four of the five factors: famine, poverty, homelessness, and unsanitary conditions. By doing so, future EL-BT and other disease outbreak events may very well be prevented.

¹⁹⁴ United Nations High Commissioner for Refugees, “UNHCR Warns Afghanistan’s Conflict Taking the Heaviest Toll on Displaced Women and Children,” UNHCR, accessed August 13, 2021, <https://www.unhcr.org/news/briefing/2021/8/611617c55/unhcr-warns-afghanistans-conflict-taking-heaviest-toll-displaced-women.html>.

¹⁹⁵ “U.S. Global Health Funding: FY2017-FY2022 Request,” n.d., 3.

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