# Penicillin: the Commodification of Medication, and World War II

By

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Strep throat, bronchitis, and gonorrhea are all relatively common infections, with distinct symptoms and causes. However, they have one distinct similarity that is unrelated to their symptoms, instead focusing on *how* they are treated. Each of these infections can be treated with a member of the penicillin family, a widely used antibiotic originally obtained from the *Penicillium notatum* mold. Penicillin, its production, and its uses have changed over time, creating a vital commodity that treats previously fatal infections. Due to a combination of media attention and wartime necessity, penicillin went from an under-researched curiosity to a vital method of treating infections during World War II. In particular, researchers such as Howard Florey and the Oxford University team, and the team in Delft, the Netherlands, played a significant role in the shift from less effective treatments such as sulfanilamide to penicillin. This paper will cover methods used to treat infections prior to penicillin's discovery, the discovery of penicillin, research that was conducted throughout the 1930s and 1940s, the impact penicillin had on World War II casualties, and public perception of the drug. It will also briefly discuss the ways in which penicillin has been produced.

Ultimately, a commodity is a product or material that is sold or exchanged for another good; in *Capital*, Karl Marx defined a commodity as an object that satisfies a need or demand in society.[1] He also declared that a commodity requires three parts. A commodity must have a value, which is based on the "socially necessary" labor needed to produce it; a use-value, which is, in essence, how the product satisfies the "human need"; and an exchange-value, which determines the worth of the product in trade.[2] The most important aspect of a commodity, however, is the fact that it can be interchanged with another commodity of the same type without

[1] Karl Marx, *Capital*, *Volume 1* (London: Electric Book Company, 2000) 53, ProQuest Ebook Central.

[2] Marx, *Capital,* 55, 60.

any noticeable differences. Amoxicillin, for example, is a member of the penicillin family. It has three brand names, each presumably sold by a different company: Amoxil, Moxatag, and Trimox. It also is sold simply as amoxicillin, the generic name.[3] However, the chemical makeup of these medications is identical—the only notable difference is the name and the cost. Therefore, penicillin and its family of medications are clearly a commodity. Penicillin-based medications can be swapped out for one another, especially in the case of name brand medications versus generic. The use-value stems from its role as a medication frequently used to treat bacterial infections, and the labor used to produce it is "socially necessary" as in many cases penicillin-based medications can be lifesaving, therefore creating value.

Prior to the discovery of penicillin, other forms of "chemotherapies," including other antibiotic medications, were used. Howard Florey, a prominent figure in the history of penicillin, published an article that described a variety of "chemotherapeutics" and "antibiosis" treatments used between the late nineteenth century and the mid-twentieth century.[4] In the case of Florey's paper, "chemotherapeutics" refers to the use of a chemical agent to prevent or treat disease, and therefore did not specifically refer to the treatment of cancer. "Antibiosis" refers to the introduction of a new organism to another, resulting in a negative outcome for the original organism.[5]

The early treatments outlined by Florey varied drastically. "Replacement therapy," for example, involved the replacement of one microorganism or disease with another to cancel out

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[3] "Amoxicillin; Side Effects, Dosages, Treatment, Interactions, Warnings," RxList, accessed March 25, 2021, https://www.rxlist.com/consumer_amoxicillin_amoxil_moxatag_trimox/drugs-condition.htm.

[4] Howard Florey, "The Use Of Micro-Organisms For Therapeutic Purposes," *The British Medical Journal* 2, no. 4427 (November 1945): 638, JSTOR;

[5] "Antibiosis," *Oxford English Dictionary*, Oxford University Press, accessed March 25, 2021, https://www.oed.com/view/Entry/8512?redirectedFrom=antibiosis#eid.

or inhibit the growth of the first—replacement therapy was the epitome of antibiosis-related treatments.[6] According to Florey, the most significant example of replacement therapy was the use of bacillus, a bacterium with multiple strains, some of which cause Anthrax and minor infections, to treat stomach problems and fevers.[7] In addition, physicians Emmerich and Löw introduced pyocyanase, the first medicine developed from an antibiotic extract.[8]

The most important pre-penicillin medication, however, was Prontosil, a sulfonamide or "sulfa drug" used to treat infections. The drug is derived from a red dye and was patented in Germany in 1932. It became widely available in 1935 and was used to treat and control diseases such as dysentery, meningitis, and pneumonia.[9] Lewis Thomas, an intern in a Boston hospital in the 1930s, described the effects of sulfa drugs as "beyond belief," with many critical patients experiencing drastic improvements within hours of being given medication.[10] The use of these medications had an impact on a wide range of medical practices and issues, including maternal mortality rates and pneumonia mortality rates. It also resulted in a shift to a more active treatment of bacterial infections.[11] The introduction of sulfa drugs to pneumonia treatment regimens resulted in a decrease in the typical patient death rate, from around 30.5 percent to around 12.3 percent.[12] Maternal mortality rates fell from 4.9 to 6.7 deaths per 1000 births in the 1920s and 1930s to 3.2 deaths per 1000 births in the early 1940s.[13] These trends continued with

[6] Florey, "The Use Of Micro-Organisms," 638; Peter C. B. Turnbull, "Bacillus," in *Medical Microbiology*, ed. S. Baron (Galveston, TX: University of Texas Medical Branch at Galveston, 1996). https://www.ncbi.nlm.nih.gov/books/NBK7699/#:~:text=Although%20anthrax%20remains%20the%20best,ophthalmitis%2C%20osteomyelitis%2C%20peritonitis%2C%20and.
[7] Florey, "The Use Of Micro-Organisms," 638.

[8] Ibid., 636.
[9] John E. Lesch, *The First Miracle Drugs: How the Sulfa Drugs Transformed Medicine* (New York: Oxford University Press, 2007) 3, ProQuest Ebook Central.
[10] Lesch, *The First Miracle Drugs*, 270.
[11] Ibid., 271.
[12] Ibid., 271.
[13] Ibid., 270.

the introduction of penicillin into medical regimens. In many cases, these numbers improved again with the addition of penicillin.

Alexander Fleming is the researcher most commonly credited with the discovery of the antibiotic properties of *Penicillium notatum*. Despite the lack of research Fleming conducted, he and his accidental discovery have become something of a legendary event. While he does deserve a portion of the credit, his discovery was, after all, an accident. In 1928, after taking a brief vacation, he returned to his lab to see the staphylococcus cultures he had been working with had been contaminated with “various micro-organisms,” or mold.[14] Fleming noted that when the staphylococcus colonies came into contact with the mold, they began to break down, suggesting that the mold had a “bacteriolytic” property.[15]

Upon discovering this, Fleming did conduct a small amount of research and later published his findings in the *British Journal of Experimental Pathology* in 1929. For example, he noted that heating it for one hour at a relatively high heat had no effect, boiling the liquid reduced its effectiveness, and “autoclaving [it] for 20 minutes at 115 degrees C. practically destroy[ed] it.” He also found that penicillin dissolves in water and saline solutions and can be safely filtered with a Seitz filter to obtain a “sterile active mould broth.”[16] He tested the toxicity of penicillin by injecting 20 cubic centimeters of the antibacterial broth into a rabbit and found it did not harm the rabbit. He also found eight hours after adding penicillin to a staphylococcus broth culture, no new colonies developed.[17] Later researchers, however, have stated that Fleming

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[14] Alexander Fleming, “On the Antibacterial Action of Cultures of a Penicillium With Special Reference to Their Use in the Isolation of *B. influenzae*,” *British Journal of Experimental Pathology* 10, no. 3 (June 1929): 226, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2048009/; Robert Gaynes, “The Discovery of Penicillin—New Insights After more than 75 Years of Clinical Use,” *Emerging Infectious Diseases* 23, no. 5 (May 2017): 849, http://dx.doi.org/10.3201/eid2305.161556.
[15] Fleming, “On the Antibacterial Action,” 226.
[16] Ibid., 228.
[17] Ibid., 232.

appeared to doubt the true value of penicillin, as he heavily emphasized his research of penicillin's ability to break down cells rather than its antibacterial abilities.[18]

It was not until later researchers, such as the team in Delft, the Netherlands and Dr. Howard Florey and the team at Oxford University, that penicillin-related research became more intense. This research did not begin until after the outbreak of World War II. Florey, who was one of the first researchers to determine that penicillin had vast potential in clinical settings, was part of the Oxford team that included Ernst Chain, Edward Abraham, and Norman Heatley. In 1940, the team was able to conduct the first trials on living organisms—in the case of their tests, mice.[19] Eight mice were injected with a strain of Streptococcus, a bacterium that can cause strep throat, scarlet fever, and other infections.[20] Four of the mice were left as a control to determine what would occur if the mice were left untreated, while four were injected with purified penicillin extracted from *Penicillium* mold. Within hours, the control mice had died, while mice that had been treated with penicillin had survived the night.[21] While the mice that had been treated eventually died, they survived three times as long as the control group.[22]

According to John Patrick Swann, the Oxford team "produced enough penicillin to treat six patients," though some died due to complications or the lack of medication.[23] The most well-known example of this is the case of Albert Alexander, a middle-aged man from Oxford,

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[18] S. N. Arseculeratne and G. Arseculeratne, "A re-appraisal of the conventional history of antibiosis and Penicillin," *Mycoses* 60, no. 5 (May 2017): 345, https://doi.org/10.1111/myc.12599.
[19] Ibid., 345.
[20] "Diseases Caused by Group A Strep," Centers for Disease Control and Prevention, Centers for Disease Control and Prevention, updated May 7, 2020, https://www.cdc.gov/groupastrep/diseases-public/index.html; Gaynes, "The Discovery of Penicillin," 850.
[21] The article by Gaynes states this event occurred in May 1939, while all other sources state it occurred in May 1940. The rest of the information in the article is corroborated by other sources. Gaynes, "The Discovery of Penicillin," 850.
[22] John Patrick Swann, "The Search for Synthetic Penicillin during World War II," *The British Journal for the History of Science* 16, no. 2 (July 1983): 155, https://www.jstor.org/stable/4026237.
[23] Swann, "The Search for Synthetic Penicillin," 155.

England whose eye had been infected with streptococcal and staphylococcal bacteria. Norman Heatley claimed that upon beginning Alexander's treatment, he observed "dramatic improvement." At the time of his treatment, Alexander was given the largest single dose of penicillin received by any human: 200 milligrams. This was followed by several additional doses. However, there was not enough penicillin to see his treatment through, and he died one month after he stopped receiving medication.[24] When he was admitted to the hospital, Alexander was originally treated with a sulfa drug, which resulted in no improvement and "gave him a terrible rash."[25]

As World War II continued, research began in the Netherlands. Researchers had access to a variety of fungi through the Centraalbureau voor Schimmelcultures (CBS). The CBS's collection of fungi included *P. notatum*. Upon their occupation of the Netherlands, Germany requested the CBS's sample of *P. notatum*, but a strain that did not produce penicillin was sent in its place.[26] At the same time, the Netherlands Yeast and Spirit Factory (NG&SF) in Delft continued to try producing penicillin, as it was still able to function despite the Nazi occupation. A discovery of note is that of *Penicillium baculatum*, a strain of *Penicillium* with greater antibacterial activity than *P. notatum*; this allowed for more efficient production of penicillin than other strains.[27] During their research, the Delft team was able to determine that five *Penicillium* strains, including *P. baculatum,* had antibiotic properties. The team conducted

[24] S. N. Arseculeratne and G. Arseculeratne, "A re-appraisal," 346.
[25] Diane Bernard, "How a miracle drug changed the fight against infection during World War II," *Washington Post*, July 11, 2020, https://www.washingtonpost.com/history/2020/07/11/penicillin-coronavirus-florey-wwii-infection/.

[26] Gaynes, "The Discovery of Penicillin," 851.
[27] Ibid., 851.

several tests—rabbits and mice, for example, were treated with penicillin after being infected by a strain of staphylococcus and recovered with no notable toxic effects.[28]

Initially, it was unclear to the Delft team if the substance extracted from their mold was the same substance as the penicillin Fleming extracted from *P. notatum*. As a result, they referred to it as Bacinol, though it was later discovered to be the same substance. However, this had the additional impact of hiding their research into penicillin from the Germans occupying the country who, as previously mentioned, were also attempting to isolate penicillin to use as medication during World War II.[29]

Wartime infections were not uncommon during World War II. While many infections resulted from injuries, other infections came in the form of venereal diseases, to which penicillin acted as a cure. A cure, it is important to note, that German soldiers did not have access to, as during World War II Germans were still frequently relying on sulfa drugs. By this point, many infections had become resistant to sulfa drugs due to overuse.[30] Allied troops, however, were able to use penicillin in various forms to cure infections. For example, penicillin powder was sprinkled on wounds before they were closed, while penicillin injections were given after the fact to encourage infection recovery and prevention.[31] Penicillin helped drastically lower the rate of gangrene in Allied soldiers, with cases dropping to about one and a half per one thousand soldiers.[32] Prisoners of war, on the other hand, received sulfa drugs due to the need to save

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[28] Marlene Burns and Piet W. M. Van Dijck, "The Development of the Penicillin Production Process in Delft, The Netherlands, During World War II Under Nazi Occupation," *Advances in Applied Microbiology* 51 (2002): 194, https://doi.org/10.1016/s0065-2164(02)51006-6.

[29] Burns and Van Dijck, "The Development of the Penicillin Production Process," 193.

[30] Richard Conniff, "Penicillin: Wonder Drug of WWII," *Military History* 30, no. 2 (July 2013): 40-43, SuperSearch.

[31] Conniff, "Penicillin: Wonder Drug of WWII," 43.

[32] Ibid., 43.

penicillin for soldiers. As a result, the rate of gangrene was much higher in this group, with some counts saying as many as thirty prisoners per one thousand suffered from it.[33] In addition, members of Britain's penicillin drug trial teams who administered it during combat and immediately after combat were told not to test the drug on enemy combatants.[34]

A variety of newspapers from the mid to late-1940s express a similar sentiment. A *New York Times* article from May 28, 1945, claimed that American soldiers in Europe during the war experienced a "remarkably low death rate," due in part to penicillin and sulfa drugs. General Paul R. Hawley, the chief surgeon of American forces in Europe, said that over one million American soldiers were treated in American hospitals in Europe, and claimed that less than 13,000 died. The death rate of hospitalized injured soldiers was around 3.9 percent, while World War I had a rate of eight percent. In addition, between 1917 and 1918, over seventeen thousand American soldiers were infected with fatal pneumonia. Only 70 American soldiers died due to pneumonia and its complications between the United States' entry into World War II and March 1945.[35] Another article, from March 1944, argued that far more sick soldiers and injured combatants in World War II would survive than in World War I as a result of modern medicine such as penicillin.[36] Perhaps most importantly, an article from April of the same year discussed vivicillin, a penicillin product that was developed in London. The drug resulted in "promising recoveries" for patients, and proved effective for issues such as "peritonitis, acute mastoiditis …

[33] Ibid., 43.
[34] Notably, the author claimed he did not follow this rule, and felt it should have been left to his discretion. Ian Fraser, "Penicillin: Early Trials In War Casualties," *British Medical Journal* 289, no. 6460 (December 1984): 1723, https://lib-proxy.radford.edu/login?url=https://www.jstor.org/stable/29517695.
[35] "96.1% of 1,375,000 Wounded Yanks Saved in Army Hospitals in Europe, Chief Reports," *New York Times*, May 28, 1945, https://search-proquest-com.lib-proxy.radford.edu/hnpwallstreetjournal/docview/107316600/DC956DE4169D4E9APQ/21?accountid=13401.
[36] M. F. Ashley Montagu, "Wartime Miracles: Medicine and the War," *New York Times*, March 19, 1944, https://search-proquest-com.lib-proxy.radford.edu/hnpwallstreetjournal/docview/106942195/DC956DE4169D4E9APQ/12?accountid=13401.

infected burns and septic wounds."[37] Unlike other penicillin-based drugs, vivicillin could "be produced in large quantities at comparatively low cost."[38] The ability to produce large amounts of penicillin-derived drugs was vital; as a result of the difficulty producing large amounts of medication affordably, what little penicillin was produced was exclusive to military use. With the ability to produce more medication affordably came the ability to potentially open its use to civilians.

Reports from the Defense Casualty Analysis System (DCAS) further support the idea that penicillin played a significant role in the war. The most important section of the data from DCAS is the number of deaths compared to the total number of soldiers. According to DCAS, 4,734,991 American soldiers participated in World War I. Slightly over 115,000 of them died, or approximately 2.5 percent. The data on World War II stated that 16,112,566 American soldiers participated, and 405,339 died. This is also approximately 2.5 percent of the total number of people serving.[39] Therefore, approximately the same proportion of American soldiers died in World War I and World War II. Several factors could have led to a higher proportion of deaths in World War II, including the amount of time the United States was involved. One can argue, however, that these numbers were kept down due to the introduction of medical advances such as penicillin. This is especially prominent when compared to the estimated number of German military deaths. While there are no absolute numbers for the German military death toll, the

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[37] Cable to *The New York Times*, "New Drug Is Found; May Cut War Toll," *New York Times,* April 30, 1944, https://lib-proxy.radford.edu/login?url=https://www-proquest-com.lib-proxy.radford.edu/historical-newspapers/new-drug-is-found-may-cut-war-toll/docview/106784914/se-2?accountid=13401https://search-proquest-com.lib-proxy.radford.edu/hnpwallstreetjournal/docview/106784914/3872F843A2634017PQ/12?accountid=13401.
[38] Cable, "New Drug is Found."
[39] "Principal Wars, 1775-1991," Defense Casualty Analysis System, Defense Casualty Analysis System, accessed April 2, 2021, https://dcas.dmdc.osd.mil/dcas/pages/report_principal_wars.xhtml.

generally accepted number is somewhere around five million.[40] When considering that the German military relied primarily on sulfa drugs and did not have access to penicillin, it becomes clear that this may have had some impact, regardless of how minimal.

One account in the *British Medical Journal* written by two British military doctors claimed that they received over 700,000,000 doses of penicillin during the first half of 1944 alone from both American and British producers; however, their use of penicillin was limited to specific types of injuries and illnesses. Despite the limits on usage and the limited number of patients treated, the authors were confident that penicillin made a drastic difference in the number of deaths. According to the article, there were "many instances where the man's life was beyond question saved solely because this drug was available."[41] Furthermore, they discussed their observations of the success of wounds treated with penicillin versus sulfa drugs. In one case, 170 soft tissue wounds were treated using penicillin powder, with almost every wound healing fully. In another, 68 wounds were sutured and treated with sulfa drugs, while a second group of wounds were sutured and treated with penicillin. The wounds treated with sulfa drugs failed to heal properly or completely 23 percent of the time, while similar failures were noted in only 17 percent of the wounds treated with penicillin.[42] A similar trend was noted in the treatment of femur fractures—slightly over one percent of femur fracture patients died due to infection when treated with penicillin, while over eight percent died while treated using methods

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[40] "World War II," Encyclopedia Britannica, Encyclopedia Britannica, Updated March 14, 2021, https://www.britannica.com/event/World-War-II.

[41] J. S. Jeffrey and Scott Thomson, "Penicillin In Battle Casualties," *British Medical Journal* 2, 4346 (July 1944): 2, https://lib-proxy.radford.edu/login?url=https://www.jstor.org/stable/20345710.

[42] J. S. Jeffrey and Scott Thomson, "Penicillin In Battle Casualties," 2.

standard for the time. About eight percent of patients required amputation when treated using the standard methods, compared to only three percent when they were treated using penicillin.[43]

It is clear that penicillin played a significant role in reducing death and long-lasting injuries during World War II. The medication's benefits were obvious as early as Florey's tests on mice. In addition, penicillin was not just useful for the treatment of infected wounds and bacterial illnesses—it was used to prevent wounds from becoming septic after treatment and in many cases cut down on the number of serious complications associated with wartime injuries, including death and amputation.[44] Due to the overlapping nature of Florey's research, the vast majority of which took place during the early 1940s, penicillin research captured the attention of researchers and governments around the world. It is impossible to say for sure if the push for penicillin and its subsequent use and production changed the outcome of the war significantly; however, research done both during and after the war proves how valuable it was in treating infections stemming from wartime injuries and therefore saving lives. It is also safe to assume that as a result of the war, research and production were kickstarted. This is especially true for production, which increased quickly near the end of the war once its effectiveness was proven.

Initially, penicillin was produced by growing the *P. notatum* and other strains of *Penicillium* in cultures. In this method, the mold grew on the surface of the culture.[45] In the late 1930s Gordon Hobday, who worked with British pharmaceutical company Boots, noted that his company kept an incubator full of several milk bottles containing a "nutrient liquid," on top of which penicillin grew.[46] Other sources describe similar occurrences elsewhere; Norman

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[43] Ibid., 3.
[44] Jeffrey and Thomson, "Penicillin In Battle Casualties," 2-4.
[45] Swann, "The Search for Synthetic Penicillin," 155.
[46] Claudia Flavell-While, "Pfizer's Penicillin Pioneers," *TCE: The Chemical Engineer*, no. 824 (February 2010): 54, SuperSearch.

Heatley's lab used "cookie tins, pie tins, milk bottles, trays, plates, and bedpans," to ferment penicillin on the surface of cultures.[47] In the case of penicillin, fermentation refers to the growth of the *Penicillium* mold. One of the commonly used methods was a ceramic bed pan, which Heatley designed. In worst case scenarios, vessels as obscure or unusual as a dog bath were used.[48] The nutrient liquid used for fermenting penicillin tended to be corn steep liquor; Andrew Moyer was the mind behind this discovery.[49] Corn steep liquor results from the creation of cornstarch, and "proved an excellent growth medium" that "boosted penicillin production."[50] The shift to corn steep liquor from the yeast extract that was previously used increased production by thirty times, drastically aiding mass production.[51]

The shift from surface fermentation to submerged fermentation was, by all accounts, a vital development. In this method of fermentation, the mold was grown in large drums that were constantly moved to provide the mold with oxygen. This method resulted in a drastic increase in the amount of penicillin one culture could produce, as *Penicillium* was able to grow throughout the vat rather than growing only on the surface of a small, shallow container.[52] One of the first, if not the first attempt to discover a more efficient alternative to surface fermentation was the "rotating pressure fermenter" developed by Color Laboratory.[53] By 1944, a factory in New York owned by Pfizer contained 14 fermentation drums, each of which could hold thousands of gallons of the nutrient liquid.[54]

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[47] Heatley was a researcher and manufacturer of penicillin at Oxford. Coniff, "Penicillin: Wonder Drug of WW2," 41.
[48] S. N. Arseculeratne and G. Arseculeratne, "A re-appraisal," 345.
[49] Peter Neushul, "Science, Government, and the Mass Production of Penicillin," *The Journal of the History of Medicine and Allied Sciences*, 48 (1993): 376, SuperSearch.
[50] Coniff, "Penicillin: Wonder Drug of WWII," 41.
[51] Neushul, "Science, Government, and the Mass Production of Penicillin," 379.
[52] Swann, "The Search for Synthetic Penicillin," 156.
[53] Neushul, "Science, Government, and the Mass Production of Penicillin", 381.
[54] Coniff, "Penicillin: Wonder Drug of WW2," 43.

Public perception played a significant role in the shift from sulfa drugs to penicillin as well. Information released to the public—through newspapers in particular—was overwhelmingly positive, perhaps to a dangerous extent. After all, very little was known about the drug and its effectiveness until 1941, when the Oxford team began human trials, while the earliest reference to penicillin in the *New York Times* was from October 1940.[55] This was only around three months after the Oxford team's original findings regarding the extraction of penicillin and their tests on mice were published in *The Lancet*.[56] Nevertheless, the section of the paper referencing penicillin referred to it as something of a miracle. Despite the lack of human trials at the time, the author noted that penicillin "may prove to be as important as sulfanilamide, the wonder-working chemical."[57] He then compared penicillin to other attempts to create alternatives to sulfa drugs, such as a substance from bacteria in soil that was able to cure pneumonia but proved toxic in tests.[58] Ultimately, the description of penicillin as an alternative to a more toxic treatment and the comparison to another "wonder drug" highlights that news sources easily accessible to the public emphasized penicillin's potential as a lifesaving drug even before it was tested on humans.

According to Gilbert Shama, the article that truly brought penicillin to the forefront of the public's minds was published in the summer of 1942 in *The Times*, a British newspaper.[59] This seems to be the case in the United States as well, though this trend occurred slightly later in the

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[55] Waldemar Kaempffert, "Science In The News: Electrically Warmed Divers Big Diomede and Science, A New 'Sulfanilamide,' Automatic Weather Station, Light On Cancer's Cause, Soaps and Eczema," *New York Times,* October 20, 1940, https://lib-proxy.radford.edu/login?url=https://www-proquest-com.lib-proxy.radford.edu/historical-newspapers/science-news/docview/105419985/se-2?accountid=13401.
[56] The Oxford team's research was published in August 1940. Gaynes, "The Discovery of Penicillin," 850.
[57] Kaempffert, "Science In The News."
[58] Kaempffert, "Science In The News."
[59] Gilbert Shama, "The role of the media in influencing public attitudes to penicillin during World War II," *Dynamis* 35, no. 1 (2013): 132, https://dx.doi.org/10.4321/S0211-95362015000100006.

United States; penicillin was consistently mentioned in the *Washington Post* starting August 1943, with several articles discussing penicillin's use and impact being published monthly. In September 1943 alone, the *Washington Post* published eight articles with references to penicillin.[60] The articles from this period consistently describe penicillin optimistically, emphasizing its importance over sulfa drugs in the treatment of a variety of infections. An article from October 1943 claimed that using penicillin to treat gonorrhea resulted in "dramatic results" and may result in gonorrhea becoming an "inconsequential infection."[61]

Another article, published in the *Wall Street Journal*, referred to penicillin and similar drugs as "miracle drugs" in the title. According to the article, penicillin and other medical advances made World War II the "'safest' war ever fought," as it played a significant role in reducing the number of military deaths caused by infected wounds. After claiming penicillin is

[60] Adele Bernstein, "Medical Group To Convene in D.C. Sept. 30," *The Washington Post*, September 20, 1943, https://lib-proxy.radford.edu/login?url=https://www-proquest-com.lib-proxy.radford.edu/historical-newspapers/medical-group-convene-d-c-sept-30/docview/151682982/se-2?accountid=13401; "Girl Once Saved By Penicillin Is in Critical Condition," *The Washington Post,* September 15, 1943, https://lib-proxy.radford.edu/login?url=https://www-proquest-com.lib-proxy.radford.edu/historical-newspapers/girl-once-saved-penicillin-is-critical-condition/docview/151682952/se-2?accountid=13401; Hanson H. Hathaway, "Walter Reed: Miracles for War – and peace: Our Soldier Patients Benefit From Hospital's Research – and Civilians, Too," *The Washington Post*, September 5, 1943, https://lib-proxy.radford.edu/login?url=https://www-proquest-com.lib-proxy.radford.edu/historical-newspapers/walter-reed-miracles-war-peace/docview/151587316/se-2?accountid=13401; "Nat. Refining Co. Sale Proposed," *The Washington Post,* September 24, 1943, https://lib-proxy.radford.edu/login?url=https://www-proquest-com.lib-proxy.radford.edu/historical-newspapers/nat-refining-co-sale-proposed/docview/151659040/se-2?accountid=13401; Drew Pearson, "Merry-Go-Round," *The Washington Post*, September 13, 1943, https://lib-proxy.radford.edu/login?url=https://www-proquest-com.lib-proxy.radford.edu/historical-newspapers/merry-go-round/docview/151596326/se-2?accountid=13401; "Penicillin Flown From N.Y. to Ga. To Aid Girl, 15," *The Washington Post*, September 5, 1943, https://lib-proxy.radford.edu/login?url=https://www-proquest-com.lib-proxy.radford.edu/historical-newspapers/penicillin-flown-front-n-y-ga-aid-girl-15/docview/151587325/se-2?accountid=13401; "Penicillin Treatment Aids Infected Girl," *The Washington Post*, September 10, 1943, https://lib-proxy.radford.edu/login?url=https://www-proquest-com.lib-proxy.radford.edu/historical-newspapers/penicillin-treatment-aids-infected-girl/docview/151602027/se-2?accountid=13401; Washington Bureau of Chicago Sun, "More Penicillin To Be Available," *The Washington Post*, September 26, 1943, https://lib-proxy.radford.edu/login?url=https://www-proquest-com.lib-proxy.radford.edu/historical-newspapers/more-penicillin-be-available/docview/151678681/se-2?accountid=13401.

[61] Frank Carey, "Medicine Since Pearl Harbor," *Washington Post*, October 24, 1943, https://search-proquest-com.lib-proxy.radford.edu/hnpnewyorktimes/docview/151669233/1FF60533082040E1PQ/17?accountid=13401.

"100 times more powerful than … sulfa drugs," the article once again referred to penicillin as a "miracle" with "amazing properties."[62]

It is clear that many of the most well-known newspapers in the United States have prominently featured articles describing penicillin and its role in World War II. Unlike articles published by researchers, such as the Oxford team's article in *The Lancet* and Fleming's original article, these are easily accessible to the public. Notably, Fleming's mentions of *Penicillium*'s antibiotic properties went largely unnoticed until World War II, when various research teams began to look more closely at it. This could be partially attributed to the lack of media attention drawing the public eye to his research. His article, which was published in the *British Journal of Experimental Pathology*, was scientific in nature, and was written with a knowledgeable, scientific audience in mind. Therefore, it is not unlikely that few members of the wider public had access to and understood the gravity of Fleming's findings. In contrast, the research done later by the Oxford team, the Delft team, and others, attracted the attention of the media, which provided the public with information. This difference may be attributed to the outbreak of World War II; as penicillin had the potential to drastically aid injured and recovering soldiers suffering from infections, the media was intrigued by it and reported on it.

Public perception may have been somewhat impacted, however, by the fact that initially, penicillin was limited to use for the war, and was not provided to the general public. This was especially common in Britain, where surface fermentation was more frequently used. The shift to improved methods of production was slow.[63] During the war, Florey stated in a radio broadcast

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[62] Sydney B. Self, "Miracle Drugs Make This the 'Safest' War for Soldiers Ever Fought by Americans," *The Wall Street Journal,* October 22, 1942, https://search-proquest-com.lib-proxy.radford.edu/docview/131418546/5276F42571864E1EPQ/7?accountid=13401.

[63] Shama, "The role of the media," 134.

that he supported this decision.[64] It is likely such regulations caused concern and frustration in the general public, as media consistently discussed penicillin and cures associated with it, such as that of Anne Miller, a young woman who became seriously ill after a miscarriage.[65] Unlike in Britain, however, the United States aimed to produce enough penicillin for use during the war and for civilians if other treatments proved ineffective—this likely improved the opinion Americans had toward penicillin.[66] To support this need, production increased significantly during 1944, when the first commercial plant for mass production, owned and operated by Pfizer, began operating, resulting in other companies following their example.[67] Penicillin continued to be pushed as something of a miracle cure throughout the early to mid-1940s, especially in the United States, despite its rarity and restrictions. This potentially canceled out any negative perceptions associated with the lack of penicillin and any regulations resulting in its exclusive use for the war effort. For example, in the United States, comic books for children outlined penicillin's usefulness.[68] Notably, penicillin was not exempt from the overwhelming amount of propaganda designed to rally civilians, soldiers, and workers during World War II. Posters were hung in places such as fermentation plants, one of which contained a message for workers that read: "Penicillin saves soldiers' lives! Men who might have died will live… if you give this job everything you've got!"[69]

Penicillin comes in a variety of forms and is used to treat a wide range of illnesses and infections. Even when disregarding the various members of the penicillin family and the modern

[64] Ibid., 135.
[65] Bernard, "How a miracle drug changed the fight."
[66] Shama, "The role of media," 137.
[67] Ibid., 137.
[68] Ibid., 134.
[69] Roswell Quinn, "Rethinking Antibiotic Research and Development," *American Journal of Public Health* 103, no. 3 (March 2013): 427, SuperSearch.

"types" of penicillin produced and sold by different pharmaceutical companies, there are different forms of penicillin. During World War II, for example, penicillin was primarily produced in two forms: a powdered form, and a liquid form. According to one account, the powdered form was primarily used for soft tissue wounds. It was put on wounds, sometimes several times, to prevent infection before being sutured closed.[70] Powders were also used on fractures that broke the skin, head wounds, and face wounds.[71] Injections, on the other hand, were used for infections that had already taken hold, such as gangrene.[72] Penicillin was also injected following the closure of wounds with powder penicillin, either to prevent or cure infection.[73] As penicillin has a relatively short half-life, injections were done frequently—sometimes as often as every three hours, as was the case with Albert Alexander, the first person the Oxford team treated with penicillin.[74] However, due to the limited nature of penicillin, especially early on, patients' urine was collected to recover penicillin. The urine was purified, and the penicillin was removed and reinjected.[75]

Clearly, penicillin played an important role between the late 1930s through World War II. The need for effective methods of treating infections after overuse of sulfa drugs resulted in drug resistance sparked a renaissance of penicillin research, led by people such as members of the Oxford and Delft teams. This interest spanned worldwide, though many breakthroughs occurred in the United States, Britain, and the Netherlands. Regardless, despite the initial lack of research conducted by Fleming and immediately after his discovery, the need for medications like

[70] Jeffrey and Thomson, "Penicillin In Battle Casualties," 2.
[71] Ibid., 3-4.
[72] Ibid., 3.
[73] Coniff, "Penicillin: Wonder Drug of WW2," 43.
[74] S. N. Arseculeratne and G. Arseculeratne, "A re-appraisal," 346.
[75] Coniff, "Penicillin: Wonder Drug of WW2," 39; Bernard, "How a miracle drug changed the fight."

penicillin and media attention brought penicillin to the forefront of many people's minds upon the outbreak of World War II.

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