Penicillin:
Breaking Bacterial Barriers

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Breaking Barriers made me think of topic ideas that were the first of their kind. I knew penicillin was the first antibiotic and was discovered by Alexander Fleming, but not much else. I decided to research penicillin and see how well it fit Breaking Barriers. After brief research, I decided the discovery fit the theme well, and I wanted to focus on Alexander Fleming. However, after further research, I realized the discovery and production of penicillin would fit the theme better than Alexander Fleming. Penicillin broke the barrier due to being the first medicine to successfully treat a multitude of bacterial infections. Therefore, I decided to focus on penicillin and its production.

Many sources proved helpful to my research about the development of penicillin. One important source was *Alexander Fleming Conquering Disease with Penicillin* by Steven Otfinoski. This book was helpful because it explained how penicillin was discovered and the process to purification and mass production. It included important topics like the mouse experiment and other crucial aspects of my project. Another important resource for my research was the *Center For Disease Control* which helped me research penicillin's role in World War II. This source mentions why the British government wanted to keep penicillin a secret during the war. The secret production in Nazi occupied countries is mentioned in this source as well, which is another crucial point of my project.

I chose to create a documentary for my project because there were many photographs and videos available during the time penicillin was developed. Using images helps tell the story of penicillin better because some of the scientific terminology used to describe the production and purification of penicillin can be hard to understand without visual aids. In my documentary, I begin my story by showing the dangers of bacterial infection before penicillin. Then, I present

Alexander Fleming's role in the discovery of penicillium. Next, I show penicillin's production and then connect it to World War II. This was an important factor in the story of penicillin, because it is why penicillin was produced so quickly.

Penicillin fits the theme, Breaking Barriers, because it was the first medicine that could successfully treat a variety of bacterial infections. Bacterial infections were leading causes of death before penicillin was widely available. Initially, after its discovery, no one was able to purify penicillium into a medicine, due to its instability. However, a team at Oxford broke that barrier and turned penicillium into a life-saving medication. Penicillin's use in World War II broke barriers of treating war wounds, and saved many Allied soldiers' lives. After penicillin was developed, the average life expectancy drastically increased. Due to the availability of penicillin and other antibiotics, most bacterial infections are no longer fatal. Some experts estimate that penicillin has saved over eighty-million lives. Penicillin broke the barrier of deadly bacterial infections. The story of the development of penicillin is still relevant today as we face other kinds of infectious diseases and search for new disease prevention and treatment.

Annotated Bibliography

Primary Sources

"The Army Nurse." *National Archives*, catalog.archives.gov/id/35895. Accessed 17 Apr. 2020. *The Army Nurse* video clip depicts soldiers during World War II which I used in my documentary. It represents the kind of dangerous operations soldiers participated in during World War II and demonstrates the great need for penicillin to help save soldiers' lives during the war.

An Artistic Rendering of Edward Jenner Vaccinating Eight-Year-Old James Phipps in 1790. *Smithsonian Magazine*, www.smithsonianmag.com/science-nature/mysterious-origins-smallpox-vaccine-180970069/. Accessed 3 Mar. 2020. Edward Jenner giving a vaccination is documented in this painting, helping to show the importance of medical discoveries. I also have an image of Allied airplanes from this source, helping to prove penicillin's importance in World War II.

British Scientist Visits Truman. 30 June 1949. *Library of Congress*, www.loc.gov/item/2002715414/. Accessed 16 Dec. 2019. This picture of Alexander Fleming helps prove how important penicillin was. It also proves that President Truman thought Fleming's discovery important.

Chain, Ernst B., and Howard W. Florey. "Further Observations on Penicillin." *The Lancet*, www.jameslindlibrary.org/wp-data/uploads/2014/07/Abraham_EP_1941.pdf. Accessed 17 May 2020. *Further Observations on Penicillin* is a primary source document and a continuation of *Penicillin as a Chemotherapeutic Agent*. This source gave me a plethora of information. It first mentions which mediums are best for growing penicillium mold, and then mentions which pathogenic organisms penicillin is effective against. Some of the first signs of antibiotic resistance are documented in this source. Studies regarding how penicillin worked were also described in this article, as well as the first human tests with penicillin.

A Crowd of People Receives Inactivated Poliovirus Vaccine in Protection, Kansas. *The History of Vaccines*, www.historyofvaccines.org/content/articles/misconceptions-about-vaccines. Accessed 3 Mar. 2020. People receiving the polio vaccine in this photograph helps document how important new vaccinations were. It helps me understand how eager people were to receive vaccinations, and how important other new medical discoveries were.

The Dome Hospital. *World Digital Library*, www.wdl.org/en/item/14464/view/1/1/. Accessed 13 Feb. 2020. The Dome Hospital image helped me give a World War I hospital example. This is important in helping me show how much penicillin was needed.

[Dr. Alexander Fleming, Half-length Portrait, Seated in Laboratory, Holding Petri Dish]. *Library of Congress*, www.loc.gov/item/95519946/. Accessed 26 Sept. 2019. I used many pictures from the Library of Congress. It provided many images that I used for research and in my documentary. It showed me what Fleming's laboratory looked like.

Dried Penicillin Culture. *Science Museum*, blog.sciencemuseum.org.uk/keeping-history-alive/. Accessed 18 Feb. 2020. *Dried Penicillin Culture* helped me show what penicillium mold looks like. I also have other images of penicillium mold from this source.

Eakins, Thomas. *The Agnew Clinic, 1889*. *Gloves Mag*, www.glovesmag.com/medical-gloves-history/. Accessed 3 Mar. 2020. *The Agnew Clinic* was a primary source image of surgeons using unsanitary methods before World War I. It helps me understand how much doctors at that time still had to learn about sanitary practices. One of the unsanitary methods it showed was surgeons operating without the utilization of gloves.

Fleming, Alexander. "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*. *National Library of Medicine*, www.ncbi.nlm.nih.gov/pmc/articles/PMC2048009/. This primary source document written by Alexander Fleming on his discovery of penicillium mold helps me understand what kinds of experiments he completed while testing the effectiveness of penicillin. A picture of the original penicillium culture is included in this article, which I used in my documentary. It also mentions his search to see if other molds had the same antibacterial qualities of penicillium. This journal article is also important because it is what inspired the Oxford Team to start working to purify penicillium.

"Focus on the 40's." *WPA Film Library*, www.wpafilmlibrary.com/videos/98475. *Focus on the 40's* was a helpful clip which showed penicillin being purified and mass produced in American factories. It helped me illustrate what mass production of penicillin looked like.

Hugo Theorell. *Nobel Prize.org*, www.nobelprize.org/prizes/medicine/1955/theorell/biographical/. Accessed 21 May 2020. *Hugo Theorell* is used in my documentary when I mention Hugo Theorell's thoughts on Fleming, Florey, and Chain winning the Nobel Prize. I also have an image of the Nobel Medal for Physiology or Medicine.

Injuries in World War One. *The United States Centennial Commission*, www.worldwar1centennial.org/index.php/injuries-in-world-war-i.html. Accessed 24 Feb. 2020. *Injuries in World War One* demonstrates how sanitary practices were taken up in that time. These pictures also show how soldiers were dying of infection. I have multiple pictures from this source.

"Miracle Penicillin Drug Saves Allied Lives." *Buy Out Footage*, www.buyoutfootage.com/pages/titles/pd_mnr_139d.php#bottom_synopsis. Accessed 24 Feb. 2020. *Miracle Penicillin Drug Saves Allied Lives* was helpful in helping me show the process of purification. This clip also shows the mass production of penicillin in American Factories during World War II.

Montgomery, Bernard. "Operations in North-West Europe from 6th June, 1944, to 5th May, 1945." *The London Gazette* [London]. *The London Gazette*, www.thegazette.co.uk/London/issue/37711/supplement/4431. Accessed 18 May 2020. *Operations in North-West Europe from 6th June, 1944, to 5th May, 1945* is a primary source report written by British Field Marshal Bernard Montgomery about the European Operations in World War II, which was printed in *The London Gazette*. Montgomery's quote, mentioning the importance of penicillin in World War II, summarized the revolutionary difference penicillin made in returning wounded soldiers to health and the fight.

"Nazi War Plants Blasted by R.A.F. in Night Raids." *National Archives*. *Nazi War Plants Blasted by R.A.F. in Night Raids* shows bombers striking Essen, Germany in an air raid. I use this video clip in my documentary to illustrate air raids that kept the Nazis from producing penicillin.

New York City Drugstore Manager. This photograph was taken from UPI. It portrays a drugstore manager putting up a sign that says "We have penicillin in stock." I use this photograph in my documentary when mentioning that penicillin became widely available after World War II.

"Normandy Invasion." *National Archives*, catalog.archives.gov/OpaAPI/media/5952/content/mopix/026/26-7-r2.mp4. Accessed 17 Apr. 2020. *Normandy Invasion* helps me illustrate the scope of the battle and the need for penicillin to treat the wounded. I use this video clip in my documentary when I mention how many soldiers involved in D-day were treated with penicillin.

Northern Regional Research Laboratory in Peoria during World War Two. *Peoria Newspaper*, www.peoriamagazines.com/pm/2019/dec/moldy-mary-or-simple-messenger-girl. Accessed 24 Feb. 2020. *Peoria Laboratory* helps show what the first lab to produce penicillin looked like. It helps prove the importance of penicillin production in the United States during World War II. I have multiple images from this source.

"Penicillin as a Chemotherapeutic Agent." *The Lancet*, www.ndorms.ox.ac.uk/files/news/19400824_florey_penicillinasachemotherapeuticagent_lancet.pdf. Accessed 16 May 2020. *Penicillin as a Chemotherapeutic Agent* is a primary source document written by Howard Florey and Ernst Chain on penicillin. It first mentions Fleming's paper and his work on penicillium mold. It then goes on to cover, in great detail, the mouse experiments. This was important and helped me better understand what was happening in these experiments.

Penicillin Propaganda. *National World War Two Museum*, www.nww2m.com/tag/penicillin/. Accessed 18 Feb. 2020. I used this picture to help show penicillin's significance in the war. It shows that the government understood penicillin’s importance and wanted to prioritize its production.

"Penicillin, Wonder Drug, Leaps in Production." *Evening Star*. *Chronicling America*, chroniclingamerica.loc.gov/lccn/sn83045462/1944-07-23/ed-1/seq-60/#date1=1938&index=2&rows=20&words=Penicillin+penicillin&searchType=basic&sequence=0&state=&date2=1945&proxtext=penicillin&y=9&x=10&dateFilterType=yearRange&page=1. Accessed 7 Apr. 2020. *Penicillin, Wonder Drug, Leaps in Production* illustrates the process of penicillin development. This 1944 article also proves the increase in penicillin.

"Prelude to War." *National Archives*, catalog.archives.gov/id/36067. Accessed 17 Apr. 2020. *Prelude to War* shows video clips of American military units marching at the beginning of World War II. I use this clip to show soldiers fighting in the military who could have needed penicillin if injured.

"Producing Penicillin." *PBS Learning*, vpm.pbslearningmedia.org/resource/odys08.sci.life.gen.producing/producing-penicillin/. Accessed 3 Mar. 2020. *Producing Penicillin* helped me show the mouse experiment. In this video clip, Florey and Chain injected penicillin into twenty five mice. It proves the importance of these experiments, crucial to the development of penicillin. I also have video clips of the battlefields of World War II. These help illustrate the need for penicillin, to save the lives of the Allied soldiers.

Professor Sir Alexander Fleming, 1881-1955. *National Galleries Scotland*, www.nationalgalleries.org/sites/default/files/styles/postcard/public/externals/177976.jpg?itok=PO98a0nV. Accessed 4 Mar. 2020. *Professor Sir Alexander Fleming* shows an image of Alexander Fleming writing in his lab. This helped me show Alexander Fleming working.

A Race Against Death. *Battles and Bandages Word Press*, battlesandbandages.wordpress.com/2012/12/08/the-power-of-penicillin/#jp-carousel-97. Accessed 24 Feb. 2020. This poster proves how important the government thought penicillin was. I also have other wartime penicillin posters from this source, showing images of wounded soldiers being treated with penicillin.

Sample of Original Penicillin. *Smithsonian Institution*, www.si.edu/search?edan_q=Alexander%2BFleming. Accessed 13 Jan. 2020. *Sample of Original Penicillin* shows some of the original mold that Alexander Fleming found. Fleming´s mold helps me show what penicillium looked like originally.

Sir Alexander Fleming – Banquet speech. NobelPrize.org. Nobel Media AB 2020. Wed. 29 Jan 2020. <https://www.nobelprize.org/prizes/medicine/1945/fleming/speech/> Alexander Fleming's Nobel Prize Speech demonstrates how Fleming reacted to winning the Nobel Prize for Medicine. I also received other information on Fleming from this source.

Sir Alexander Fleming, 1881-1955. 11 Mar. 1955. *Library of Congress*, www.loc.gov/item/2002697629/. Accessed 26 Sept. 2019. I used this picture of Alexander Fleming in my documentary.

[Sir Alexander Fleming, Half Portrait, Seated]. 1945. *Library of Congress*, www.loc.gov/item/2005685189/. Accessed 26 Sept. 2019. I used this picture of Fleming in my documentary.

Sir Howard Florey. *Nobel Prize.org*, www.nobelprize.org/prizes/medicine/1945/florey/biographical/. Accessed 17 Feb. 2020. *Sir Howard Florey* helped me show in my documentary what he looked like. I also have his Nobel Prize speech from this source. His speech shows his reactions of winning the Nobel Prize for Medicine.

Smithsonian Institution. www.si.edu. Accessed 3 Feb. 2020. I used many pictures of penicillin from this website. They help show what penicillin looked like at the time of World War II.

Smithsonian Institution Archives, Smithsonian Institution. "Smithsonian Learning Lab Resource: Harden Franklin Taylor (Left) and Bernard Godwin (Right)." *Smithsonian Learning Lab*, Smithsonian Center for Learning and Digital Access, 16 Feb. 2019. learninglab.si.edu/q/r/3518399. Accessed 16 Dec. 2019. These pictures of Alexander Fleming show how important Alexander Fleming was. In this picture, two scientists are carrying a portrait of Alexander Fleming.

Smoke Rising from the London Docklands after the First Mass Air Raid on the British Capital, Sept. 7, 1940. Britannica, www.britannica.com/event/Battle-of-Britain-European-history-1940. Accessed 23 Feb. 2020. The picture of smoke rising from the London Docklands was very helpful in showing the destruction of the Battle of Britain. I also have other photographs from this source of the Axis powers and Field Marshal Bernard Montgomery.

"13 Hours That Saved Britain." *YouTube*, 3 Feb. 2018. Accessed 27 Feb. 2020. *Thirteen Hours That Saved Britain* was a documentary with video clips from the Battle of Britain. These clips show the destruction of buildings in London after the Battle of Britain. They show me the dangers faced by Florey and Chain living in Britain while it was under attack by Nazi Germany.

Trail Blazers- Cartoon Showing Medical Discoveries. *The Royal Society*. Accessed 4 Mar. 2020. *Trail Blazers* was helpful in helping me prove the importance of penicillin. In this image, important medical discoveries were listed, first among these was penicillin.

Tuberculosis Patient Being Cured. *PBS*, www.pbs.org/wgbh/americanexperience/features/plague-gallery/. Accessed 17 Apr. 2020. This image of a tuberculosis patient being cured is used in my documentary. It shows that bacterial infections can be treated because of penicillin.

U.S Federal Government, "Penicillin poster from World War II," *USU Digital Exhibits*, accessed February 24, 2020, http://exhibits.lib.usu.edu/items/show/18775. *Penicillin Poster from World War II* illustrates that penicillin was important in World War II. It also shows that the U.S government knew that penicillin was important and wanted it produced to save Allied lives.

University of Wisconsin-Madison News. news.wisc.edu/d-day-invasion-was-bolstered-by-uw-madison-penicillin-project/. Accessed 17 Apr. 2020. This website contained primary source interviews of penicillin researchers which helped me understand how important the collaboration of researchers, government agencies, and manufacturers was in the process of producing penicillin.

U.S. Scientists Aid in the Development of Penicillin, New Life-Saving Drug for United Nations' Battlefront. *Library of Congress*, www.loc.gov/item/93513220/. Accessed 6 Jan. 2020. *U.S Scientists Aid in the Development of Penicillin* proves that penicillin was important in the United States war effort.

Yeast and Spirits Factory. *Postcards From.nl*, postcardsfrom.nl/index.php?page=27&p1=Delft+en+Westland&p2=1004&display=lijst. Accessed 21 May 2020. I used this image when mentioning the Netherlands' work on penicillin. *Yeast and Spirits Factory* shows the factory where penicillin was produced in the Netherlands under the codename Bacinol.

Secondary Sources

Antibiotics. *New Statesman*. Accessed 4 Mar. 2020. *Antibiotics* helps me show penicillin and other antibiotics in their modern forms.

Bacteria in Photos. www.bacteriainphotos.com/Alexander_Fleming_and_penicillin.html. Accessed 23 Feb. 2020. The statistics from this website were very useful in helping show about how many lives penicillin has saved.

Benson, Sonia, et al. "Penicillin." *UXL Encyclopedia of U.S. History*, vol. 6, UXL, 2009, pp. 1207-1209. *Gale In Context: Middle School*, https://link.gale.com/apps/doc/CX3048900473/MSIC?u=va_s_039_0071&sid=MSIC&xid=a549a60b. Accessed 3 Oct. 2019. This article helped me with my early research to help me understand more about penicillin.

"The Discovery of Penicillin—New Insights After More Than 75 Years of Clinical Use." *CDC*, wwwnc.cdc.gov/eid/article/23/5/16-1556_article. Accessed 10 Feb. 2020. *The Discovery of Penicillin—New Insights After More Than 75 Years of Clinical Use* shows penicillin's use in the war effort. It was especially helpful because of its information on penicillin production in other countries and Nazi involvement.

Figure 7. *Montana.edu*, www.cs.montana.edu/webworks/projects/stevesbook/contents/chapters/chapter004/section005/blue/page002.html. Accessed 15 Feb. 2020. This image of *Figure 7* shows deadly *staphylococcus* bacteria.

First Day of Spring. Composed by David Hilowitz. *Free Music Archive*. Accessed 22 May 2020. First Day of Spring is used as background music in my documentary.

Gotterfried, Ted. *Alexander Fleming Discoverer of Penicillin*. Book Report Biographies, 1997. The information I received from this book helped me with my background research on Fleming.

Ho, David. "Alexander Fleming. (Cover Story)." *TIME Magazine*, vol. 153, no. 12, Mar. 1999, p. 117. *EBSCOhost*, search.ebscohost.com/login.aspx?direct=true&db=f6h&AN=1658745. I used this resource to help me with research on Alexander Fleming. It also had information on the leading causes of death before and after penicillin.

"Howard Walter Florey and Ernst Boris Chain." *Science History Institute*, www.sciencehistory.org/historical-profile/howard-walter-florey-and-ernst-boris-chain. Accessed 30 Jan. 2020. I used pictures of Florey and Chain from this site in my documentary.

How to Teach Patients about Antibiotics. *Daily Nurse*, dailynurse.com. Accessed 17 Apr. 2020. *How to Teach Patients about Antibiotics* shows that we still use penicillin and other antibiotics to treat bacterial infection. I use this image to illustrate a patient taking penicillin.

Kaye, Judith. *The Life of Alexander Fleming*. Twenty-First Century Books, 1993. I used this book to help me with my research. It helped me understand more about Fleming's life. I also have pictures from this book.

Maurois, André. *The Life of Sir Alexander Fleming*. Translated by Gerald Hopkins, E.P Dutton & Co., Inc, 1959. *The Life of Sir Alexander Fleming* gave information on Alexander Fleming's life. It was very detailed and helped with my research on Fleming. It described his early life, and his work with penicillin.

National Library of Medicine. www.ncbi.nlm.nih.gov/pmc/articles/PMC5403050/. Accessed 5 Mar. 2020. The National Library of Medicine gave me important information on penicillin. It gave information about its development and importance in World War II.

Otfinoski, Steven. *Alexander Fleming Conquering Disease with Penicillin*. Facts on File, 1992. Makers of Modern Science. *Alexander Fleming Conquering Disease with Penicillin* had information not only on Alexander Fleming, but also the development and production of penicillin. It explains his work with Sir Almroth Wright in World War I and his experiments with antiseptics. This book also had information on the role penicillin played in World War II.

Penicillin. *Smithsonian Institution*, www.si.edu/search?edan_q=Penicillin. Accessed 13 Jan. 2020. I used this picture of a vial of penicillin to present penicillin as the medicine.

Penicillium chrysogenum. *Wisconsin University*, botit.botany.wisc.edu/toms_fungi/nov2003.html. Accessed 3 Mar. 2020. Wisconsin University has a picture of Penicillium chrysogenum. I took a photograph from this website to show what the strain of penicillium looks like.

Penicillium Mold in a Petri Dish. *Vanderbilt Medical Center*, www.mc.vanderbilt.edu/lens/article/?id=221&pg=999. Accessed 4 Mar. 2020. *Penicillium Mold in a Petri Dish* illustrates what penicillium mold cultures look like. It shows what the labs Alexander Fleming sent mold cultures to had to work with to try to produce penicillin.

"Pfizer's Penicillin Pioneers – Jasper Kane and John McKeen." *The Chemical Engineer*, www.thechemicalengineer.com/features/cewctw-pfizers-penicillin-pioneers-jasper-kane-and-john-mckeen/. Accessed 26 Feb. 2020. *Pfizer's Penicillin Pioneers – Jasper Kane and John McKeen* focuses on the process of purification through deep-tank fermentation. It also gave me information on the importance of penicillin in the D-day landings. I also have an image from this source that shows deep-tank fermentation.

Tocci, Salvatore. *Alexander Fleming: The Man Who Discovered Penicillin*. Enslow Publishers, Inc., 2002. *Alexander Fleming: The Man Who Discovered Penicillin* gave information on the discovery of penicillium and Alexander Fleming's life.

USDA Official Seal. *USDA Special Collections*, specialcollections.nal.usda.gov/official-seal-usda. Accessed 17 Apr. 2020. *USDA Official Seal* is used in my conclusion to prove that governments played a role in the development of penicillin.

The War Against Germs. *The War Against Germs* gave me important background information on germs and germ theory. It gave information about key scientists who helped develop germ theory. This book also gave information about penicillin.