

Revolutionizing Medicine:
John Gibbon's Heart-Lung Machine

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Historical Paper

"During that long night, helplessly watching the patient struggle for life as her blood became darker and her veins more distended, the idea naturally occurred to me that if it were possible to...inject continuously the now-red blood into the patient's arteries, we might have saved her life." --John Heysham Gibbon, Jr., M.D.

Great revolutions often begin with a defining moment of inspiration. After weeks of struggling with the sudden death of a patient, Dr. John Gibbon made the decision to create the first heart-lung machine. The heart-lung machine became one of the first major breakthroughs in the field of cardiovascular medicine.¹ By taking over the functions of the human heart and lungs, the heart-lung machine provided doctors with the opportunity to perform life-saving operations.² Many modern surgeries and apparatuses stem from John Gibbon's original heart-lung machine. One such invention is the extracorporeal membrane oxygenation machine, or ECMO. The ECMO machine is most often used to aid premature babies with underdeveloped lungs. While studies have shown that not all effects of the heart-lung machine are positive, the benefits to the medical community and the field of cardiopulmonary surgery far outweigh the negative cognitive deficiencies experienced by patients. Although the heart-lung machine may have negative side-effects for patients, the invention of the heart-lung machine successfully revolutionized the field of medicine because it provided the foundation for future developments pertaining to the construction of future heart-lung machines and paved the way for further advancements in the cardiopulmonary medical field.

John Gibbon is recognized as the creator of the first successful heart-lung machine; however, many other scientists at this time also strove to create a machine that performed the functions of the heart and lungs. After hearing that his sister had a potentially fatal cardiac

¹ Michael E DeBakey MD, "John Gibbon and the heart-lung machine: a personal encounter and his import for cardiovascular surgery," CTS Journals Net, accessed September 25, 2011, last modified 2003, <http://ats.ctsnetjournals.org/cgi/content/full/76/6/S2188>.

² Kelli A Miller, "The Invention of the Heart-Lung Machine Launches the Era of Open-Heart Surgery," in *Gale Virtual Reference Library* (2001), accessed October 1, 2011, last modified 2001.

disease, Charles Lindbergh, an aviator, contacted Alexis Carrel, a research surgeon, in an attempt to save his sister's life. Instead of creating a system that would completely support a patient with nonfunctioning heart and lungs, Carrel invented a pump that allowed the heart to remain living while outside the patient's body. Although partially successful in their efforts, Lindbergh and Carrel did not create a machine which could fully support a patient. In addition to Lindbergh and Carrel, Clarence Dennis, a general surgeon, also endeavored to develop a heart-lung machine.³ Dennis successfully created a heart-lung machine despite a later commencement for his project than others. Before John Gibbon finished creating a heart-lung machine, Dennis had already twice attempted open heart surgery using his own creation.⁴ Both of Dennis' surgeries failed, one due to misdiagnosis and the other due to human error. Dennis' failed surgeries prevented him from being the first doctor to successfully use a heart-lung machine to perform open heart surgery.⁵

Although many people thought of heart surgery as impossible, John Gibbon, mourning the death of a patient, projected the idea of building a machine which could imitate the functions of the heart and lungs. At the beginning of his research, John Gibbon's interests were solely to aid patients with a pulmonary embolus, a blood clot in the pulmonary artery.⁶ While at Massachusetts General Hospital in the 1930s, Gibbon began working as a junior research fellow, the experience that provided the impetus for his work on the heart-lung machine.⁷ The basic idea behind Gibbon's machine was to pump deoxygenated blood from the right side of the heart into

³ David K.C. Cooper, *Open Heart: The Radical Surgeons Who Revolutionized Medicine* (New York: Kaplan Publishing, 2010), 144.

⁴ IBID.

⁵ IBID.

⁶ David K.C. Cooper, *Open Heart: The Radical Surgeons Who Revolutionized Medicine* (New York: Kaplan Publishing, 2010), 148.

⁷ IBID, 147.

a machine that would expose it to oxygen.⁸ The now oxygen-rich blood would return to the left side of the heart where it would then be pumped throughout the rest of the body.⁹ He first experimented on cats, then dogs, and, finally, he used his machine to operate on humans.¹⁰ Early experiments proved dangerous.¹¹ Nascent heart-lung machines often leaked blood and caused hemorrhaging.¹² After World War II, which he spent as a surgeon in the United States Army, Gibbon returned to Jefferson Medical College where he became the Chair of Surgery, directing surgical research.¹³ Diminishing funding and support inhibited Gibbon's research efforts and curtailed further developments on the heart-lung machine.¹⁴

Gibbon's luck changed he met Thomas Watson, the Chairman for International Business Machines, or IBM.¹⁵ Watson agreed to take a chance and aided Gibbon with the finances involved in researching and building a heart-lung machine. By January of 1952, Gibbon deemed the heart-lung machine ready for use on humans. Gibbon's first attempt at utilizing the heart-lung machine on humans failed due to misdiagnosis.¹⁶ On May 6, 1953, John Gibbon successfully

⁸ "Heart-lung Machine," The Heart Surgery Forum, accessed November 4, 2011, <http://www.google.com/imgres?q=heart-lung+machine&hl=en&biw=1613&bih=791&gbv=2&tbn=isch&tbnid=m7tkeXHHvtgx3M:&imgrefurl=http://www.hsforum.com/stories/storyReader%241486&docid=pGlclpmGIrwCzM&imgurl=http://mmserver.cjp.com/images/test/HeartGross.jpg&w=299&h=322&ei=ll3ATsGoKIWFIAK2v9WbAw&zoom=1&iact=rc&dur=129&sig=100909004812815424667&page=1&tbnh=126&tbnw=117&start=0&ndsp=34&ved=1t:429,r:0,s:0&tx=80&ty=57>.

⁹ IBID.

¹⁰ Denton A Cooley MD, "John H. Gibbon: The First 20 Years of the Heart-Lung Machine," *Historical Perspectives* 24, no. 1 (1997): accessed September 23, 2011, <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC325389/pdf/thij00024-0011.pdf>.

¹¹ Kelli A Miller, "The Invention of the Heart-Lung Machine Launches the Era of Open-Heart Surgery," in *Gale Virtual Reference Library* (2001), accessed October 1, 2011, last modified 2001.

¹² IBID.

¹³ David K.C. Cooper, *Open Heart: The Radical Surgeons Who Revolutionized Medicine* (New York: Kaplan Publishing, 2010), 151.

¹⁴ Kelli A Miller, "The Invention of the Heart-Lung Machine Launches the Era of Open-Heart Surgery," in *Gale Virtual Reference Library* (2001), accessed October 1, 2011, last modified 2001.

¹⁵ IBID.

¹⁶ IBID.

made use of the heart-lung machine.¹⁷ The first successful use of the heart-lung machine revolutionized the medical field because it changed the way that people viewed cardiopulmonary surgery. Because surgeons could now make use of a machine which took over the actions of the heart and the lungs, their options for aiding patients with health issues such as pulmonary emboli increased considerably.¹⁸ Surgeons no longer had to hurriedly attempt to perform a pulmonary embolectomy to aid patients with pulmonary emboli, rather they could now make use of the heart-lung machine and have more time to perform the procedure.¹⁹

While the heart-lung machine provides surgeons with time to repair patients' hearts, studies have shown that patients suffer from cognitive deficits in the years after surgery. After hearing about some of the problems experienced by patients who relied on the heart-lung machine during a previous surgery, Mark F. Newman and his partners performed five cognitive, gaining knowledge through reason, tests on 261 heart-bypass patients.²⁰ Newman and his partners performed the tests four times over six months--one week before the patient's hospitalization, during the week after the operation, six weeks after the operation, and six months after the operation. When Newman tested patients the week after surgery, he found 53 percent of the tested population failed to match their pre-procedure cognitive performance. After six weeks, 36 percent of patients continued to experience the negative cognitive effects after utilizing the heart-lung machine. The final tests, six months after surgery, revealed that 24 percent of patients tested originally continued to experience cognitive deficits.²¹ Five years later, Newman and his

¹⁷ Kelli A Miller, "The Invention of the Heart-Lung Machine Launches the Era of Open-Heart Surgery," in *Gale Virtual Reference Library* (2001), accessed October 1, 2011, last modified 2001.

¹⁸ Stephan Klaidman, *Saving the Heart: The Battle to Conquer Coronary Disease* (New York: Oxford University Press, 2000), 34.

¹⁹ Stephan Klaidman, *Saving the Heart: The Battle to Conquer Coronary Disease* (New York: Oxford University Press, 2000), 34.

²⁰ Bruce Stutz, "Pumphead: Does the heart-lung machine have a dark side?" *Scientific American*, accessed September 23, 2011, last modified January 9, 2009, <http://www.scientificamerican.com/article.cfm?id=pumphead-heart-lung-machine&page=5>.

²¹ *IBID.*

team decided to retest the original patients another time. Five years after their surgery, 42 percent of patients tested so inadequately that Newman and his partners declared them cognitively impaired.²² After receiving shocking results, Newman and his team searched for reasons as to why patients of the heart-lung machine experienced such significant side-effects. Newman and his team categorized their theories into two groups: problems involving the heart-lung machine and those not involving the heart-lung machine. Newman thought that the contact between the tubing of the heart-lung machine and the patient's blood cells, air bubbles, and debris, such as corroded tubing, arterial plaque, and clotted blood cells, might be causes of the noticed decline in cognitive abilities. He also thought that inflammation, hypoxia, incorrect body temperature, arrhythmias, and lowered blood pressure could be influencing factors not having to do with the heart-lung machine. After Newman's studies became public, he received over 4,000 emails from bypass patients.²³ Patients felt that their personal experiences now had scientific explanation and thanked Newman for his studies. Because of the deficits of the heart-lung machine, doctors strove to improve Gibbon's original machine.

John Gibbon's heart-lung machine provided the impetus needed to drive other doctors to improve the heart-lung machine and heart surgery. In 1960, Wilfred Bigelow had an idea to combine Dr. Gibbon's heart-lung machine with the technology of hypothermic cooling, also known as extracorporeal cooling.²⁴ A machine cooled blood during the operation and warmed the blood up to normal temperature after the operation took place.²⁵ Hypothermic cooling allowed surgeons to operate on a motionless and dry heart. Hypothermic cooling greatly

²² Bruce Stutz, "Pumphead: Does the heart-lung machine have a dark side?" *Scientific American*, accessed September 23, 2011, last modified January 9, 2009, <http://www.scientificamerican.com/article.cfm?id=pumphead-heart-lung-machine&page=5>.

²³ IBID.

²⁴ Kelli A Miller, "The Invention of the Heart-Lung Machine Launches the Era of Open-Heart Surgery," in *Gale Virtual Reference Library* (2001), accessed October 1, 2011, last modified 2001.

²⁵ Kelli A Miller, "The Invention of the Heart-Lung Machine Launches the Era of Open-Heart Surgery," in *Gale Virtual Reference Library* (2001), accessed October 1, 2011, last modified 2001.

increased the number of possibilities for heart surgery. The body's need for oxygen would decrease while in a state of hypothermia, allowing multiple organs in the body to survive without oxygen for longer periods of time than when the body's temperature increased.²⁶ This further gave the surgeons the ability to operate on the arteries of the heart.²⁷ Without extracorporeal cooling, surgeons would not have had access to the inside of the heart, preventing them from aiding patients with internal defects.²⁸ These new advancements led to a more commercial heart-lung machine, the Mayo-Gibbon device. John Kirklin, of the Mayo Clinic, and his coworkers developed the Mayo-Gibbon device. Widely used in the 1950s and 1960s, the Mayo-Gibbon device refined most aspects of the original heart-lung machine.²⁹ Kirklin utilized his machine to aid in repairing an atrial septal defect, a congenital hole in the heart, in 1955.³⁰

The invention of the heart-lung machine paved the way for further advancements in the cardiopulmonary field and medicine in general. The heart-lung machine allowed the idea of organ transplants to advance further and become more common and less dangerous.³¹ In 1967, in South Africa, surgeon Christian Barnard performed the first human heart transplant. The success of Barnard's risky operation inspired other surgeons to push the boundaries of surgery further than ever before. Because the heart-lung machine constantly provided the patient's body with oxygenated blood, surgeons focused on performing previously unimaginable procedures.

Kidney and liver transplants became a possibility instead of solely an idea because of the heart-

²⁶ IBID.

²⁷ Kelli A Miller, "The Invention of the Heart-Lung Machine Launches the Era of Open-Heart Surgery," in *Gale Virtual Reference Library* (2001), accessed October 1, 2011, last modified 2001.

²⁸ D.G. Melrose, "Types of Heart-lung Machines Used in Extra-Corporeal Circulation," *Postgraduate Medical* 37 (1961): 639.

²⁹ IBID.

³⁰ Edwin Rodriguez-Cruz and Stuart Berger, "Extracorporeal Membrane Oxygenation," Medscape Reference, accessed November 4, 2011, last modified March 29, 2011, <http://emedicine.medscape.com/article/1818617-overview>.

³¹ Kelli A Miller, "The Invention of the Heart-Lung Machine Launches the Era of Open-Heart Surgery," in *Gale Virtual Reference Library* (2001), accessed October 1, 2011, last modified 2001.

lung machine. Again in the mid 1970s, the heart-lung machine allowed for advancements in the medical field. Due to his ability to make use of the heart-lung machine, Dr. Norman Shumway gained the ability to detect rejection attacks in tissue.³² He and his team did this by carefully feeding a catheter into the heart of the patients, removing a piece of cardiac muscle, and examining the muscle specimen to determine if the patient needed an increase in the amount of immunosuppressant medication. The heart-lung machine, along with the work of Dr. Shumway, led to the discovery of cyclosporin, an immuno-suppressant. Cyclosporin suppressed the immune system, making it easier for the body to accept new organs. While cyclosporin suppressed the immune system enough so that the body did not attack the new organ, it did not suppress the immune system so much that the patient became overly susceptible to disease.³³

John Gibbon's heart-lung machine, although altered and improved, continues to affect medicine today. In 1994, Dr. Randas Batista thought of a new way to aid patients with enlarged hearts by using the heart-lung machine.³⁴ He felt that by decreasing the size of the enlarged portion of the heart and increasing its efficiency, he could decrease the number of donor hearts needed. He utilized the heart-lung machine to attempt his procedure and has experienced varying results.³⁵ The heart-lung machine still aids in organ transplantation. In January of 2000, 261 medical facilities in the United States made use of a program for organ transplants.³⁶ With less than 2,500 hearts available for donation each year, the modern issue with heart transplants lies in not having enough hearts to aid the approximately two million people that suffer from congestive

³² David H Koch, "Pioneers of Heart Surgery," NOVA, accessed October 1, 2011, last modified April 8, 2011, <http://www.pbs.org/wgbh/nova/body/pioneers-heart-surgery.html>.

³³ IBID.

³⁴ IBID.

³⁵ IBID.

³⁶ Kelli A Miller, "The Invention of the Heart-Lung Machine Launches the Era of Open-Heart Surgery," in *Gale Virtual Reference Library* (2001), accessed October 1, 2011, last modified 2001.

heart failure.³⁷ In the United States alone, surgeons performed more than 20,000 heart-transplants from 1988-1999.³⁸ Improvements to the heart-lung machine also allow for the heart-lung machine to experience more success. The improved heart-lung machines now have polyvinyl tubing, which cells do not adhere to, and centrifugal pumps, which do not crush red blood cells. These improvements prevent debris from forming and prevent cells from becoming damaged, therefore decreasing negative side effects for the patient. The addition of woven polymer thread screens also decreases the number of large particles of debris. By using a screen to filter emboli ranging from 0.2 to 0.5 microns in size, the amount of debris entering the patient's blood stream decreases, improving the health of the patient after surgery.³⁹ The new heart-lung machine makes use of gas exchangers to reduce the size of bubbles created in the circulating blood.⁴⁰ Better temperature controls also allow doctors to keep patients at healthy body temperatures during surgery with the heart-lung machine.⁴¹ More recently, the portability of the heart-lung machine increased.⁴² Newer, portable heart-lung machines support the total circulatory needs of a patient without needing the larger equipment of stationary heart-lung machines.⁴³ These portable heart-lung machines can be used in emergencies and can be ready for use within a few minutes.⁴⁴ When a patient suffers from a myocardial infarction or pulmonary

³⁷ David H Koch, "Pioneers of Heart Surgery," NOVA, accessed October 1, 2011, last modified April 8, 2011, <http://www.pbs.org/wgbh/nova/body/pioneers-heart-surgery.html>.

³⁸ Kelli A Miller, "The Invention of the Heart-Lung Machine Launches the Era of Open-Heart Surgery," in *Gale Virtual Reference Library* (2001), accessed October 1, 2011, last modified 2001.

³⁹ IBID.

⁴⁰ Bruce Stutz, "Pumphead: Does the heart-lung machine have a dark side?" *Scientific American*, accessed September 23, 2011, last modified January 9, 2009, <http://www.scientificamerican.com/article.cfm?id=pumphead-heart-lung-machine&page=5>.

⁴¹ IBID.

⁴² Mark Kurusz and Joseph B Zwischenberger, "Percutaneous Cardiopulmonary Bypass for Cardiac Emergencies," *Cardiothoracic Surgery*.

⁴³ IBID.

⁴⁴ Mark Kurusz and Joseph B Zwischenberger, "Percutaneous Cardiopulmonary Bypass for Cardiac Emergencies," *Cardiothoracic Surgery*.

embolism, a portable heart-lung machine may be used to aid the patient.⁴⁵ Although portable heart-lung machines aid in many life-threatening situations, they remain in use for temporary support until a diagnosis is obtained for the patient's treatment or until doctors find another form of long-term support.⁴⁶ Inspired by Gibbon's machine, other doctors created the ECMO, extracorporeal membrane oxygenation, machine.⁴⁷ This machine is used for long term support of the lungs of premature babies and allows time for a patient's heart and lungs to recover. The ECMO machine can also be used as a bridge to transplant.⁴⁸

John Gibbon revolutionized medicine with his invention of the heart-lung machine. His ability to push forward despite the beliefs of others during his time allowed him to create an influential and essential medical machine. Through his countless hours of work and research, John Gibbon contributed greatly to medicine. The heart-lung machine's ability to take over the functions of a patient's heart and lungs truly revolutionized multiple aspects of medicine. Despite the cognitive decline in patients who used the heart-lung machine during a surgery, the heart-lung machine successfully revolutionized the medical field because the advantages of the heart-lung machine outweigh the disadvantages. The heart-lung machine provided other doctors with the motivation and resources to improve surgery in general. Through improvements, the heart-lung machine gained use in organ transplants and continues to aid patients in a multitude of situations. The heart-lung machine's impact, both past and continuing, revolutionized the medical field.

⁴⁵ IBID.

⁴⁶ IBID.

⁴⁷ Edwin Rodriguez-Cruz and Stuart Berger, "Extracorporeal Membrane Oxygenation," Medscape Reference, accessed November 4, 2011, last modified March 29, 2011, <http://emedicine.medscape.com/article/1818617-overview>.

⁴⁸ IBID.

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<http://ats.ctsnetjournals.org/cgi/content/full/76/6/S2188>.

"John Gibbon and the Heart-Lung Machine: A Personal Encounter and his Import for Cardiovascular Surgery" is a primary source written by Michael E DeBakey. DeBakey is a cardiac surgeon and director of The Methodist DeBakey Heart and Vascular Center. "A Personal Encounter" discusses John Gibbon's personal life, the effects of the heart-lung machine, and the creation of the heart-lung machine, useful information for background paragraphs. "A Personal Encounter" discusses the revolution created by John Gibbon's creation of the first heart-lung machine. It also provides many pictures of the heart-lung machine, aiding the understanding of the reader.

2. "Heart-lung Machine." The Heart Surgery Forum. Accessed November 4, 2011.
<http://www.google.com/imgres?q=heartlung+machine&hl=en&biw=1613&bih=791&gbv=2&tbnid=m7tkeXHHvtgx3M:&imgrefurl=http://www.hsforum.com/stories/storyReader%241486&docid=pGIclpmGIrwCzM&imgurl=http://mmserver.cjp.com/images/test/HeartGross.jpg&w=299&h=322&ei=Il3ATsGoKIWFiAK2v9WbAw&zoom=1&iactrc&dur=129&sig=100909004812815424667&page=1&tbnh=126&tbnw=117&start=0&ndsp=34&ved=1t:429,r:0,s:0&tx=80&ty=57>.

"Heart-Lung Machine" is a primary source picture. The photographer is unknown. This picture appears on the website "The Heart Surgery Forum," which is a cardiothoracic multimedia journal. "Heart-Lung Machine" provides a simple, basic picture of a heart-lung machine attached to a human heart. It allows the viewer to gain a sense of how the heart-lung machine works in conjunction with the heart. Because the heart-lung machine is complicated, the simpler picture provided aids the viewer's understanding of the often complex description of a heart-lung machine.

3. Stutz, Bruce. "Pumphead: Does the Heart-Lung Machine Have a Dark Side?" Scientific American. Accessed September 23, 2011. Last modified January 9, 2009. <http://www.scientificamerican.com/article.cfm?id=pumphead-heart-lung-machine&page=5>.

"Pumphead: Does the Heart-Lung Machine Have a Dark Side?" is a primary source written by Bruce Stutz. Mr. Stutz is writing about personal experience. "Pumphead" discusses many emotional and mental effects experienced by patients after they have used the heart-lung machine and their possible causes. It also discusses the changes and improvements that have been recently made to the heart-lung machine. "Pumphead" provides valuable, firsthand experience with the heart-lung machine and the legacy of the heart-lung machine.

Secondary Sources:

1. Bigelow, W. G., W.K. Lindsay, and W.F. Greenwood. "Hypothermia: Its Possible Role in Cardiac Surgery: An Investigation of Factors Governing Survival in Dogs at Low Body Temperatures." *Annals of Surgery* 132, no. 5 (November 1950). Accessed November 5, 2011. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1616603/pdf/annsurg01398-0005.pdf>.

"Hypothermia: Its Possible Role in Cardiac Surgery: An Investigation of Factors Governing Survival in Dogs at Low Body Temperatures" is a secondary source written by W.G. Bigelow, W.K. Lindsay, and W.F. Greenwood. Wilfred G. Bigelow is known for his work in cardiac surgery, the creation of the artificial pacemaker, and the use of hypothermia in surgery. He studied under Dr. Blalock, the "father of cardiac surgery," who aided in creating the Blalock-Taussig shunt. "Hypothermia" provided information pertaining to the use of hypothermia in surgery.

2. Cooper, David K.C. *Open Heart: The Radical Surgeons Who Revolutionized Medicine*. New York: Kaplan Publishing, 2010.

Open Heart: The Radical Surgeons Who Revolutionized Medicine is a secondary source written by David K.C. Cooper. Cooper is a professor of surgery and completed his PhD in surgery. He has researched and completed training in cardiovascular surgery. *Open Heart* provides information pertaining to John Gibbon's personal life, his struggles to achieve success with his heart-lung machine, and other doctors who attempted to create a heart-lung machine, or a similar device, before he did. Because of the depth of information in *Open Heart*, the reader is able to gain a more thorough understanding of the background behind the idea of a heart-lung machine before delving into Dr. Gibbon's endeavors specifically. Overall, *Open Heart* provides information regarding the heart-lung machine that is useful both in background paragraphs and body paragraphs.

3. Cohn, Lawrence H. "Fifty Years of Open Heart Surgery." *Circulation: Journal of the American Heart Association Journal* (May 2003): 2168-2170. Accessed September 28, 2011. doi:10.1161/01.CIR.0000071746.50876.E2.

"Fifty Years of Open Heart Surgery" is a secondary source written by Lawrence H. Cohn. Cohn is a cardiac surgeon and researcher. He is known for his noninvasive heart valve surgeries and is currently a professor at Harvard University. "Fifty Years" provides information about other heart support research experiments. It also provides useful information about the background work Dr. Gibbon performed to get to his final results. Because of the background information provided, readers are able to understand the how John Gibbon got the idea to create a heart-lung machine.

4. Cooley, Denton A. "John H. Gibbon: The First 20 Years of the Heart-Lung Machine." *Historical Perspectives* 24, no. 1 (1997): 1-8. Accessed September 23, 2011. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC325389/pdf/thij00024-0011.pdf>.

"John H. Gibbon: The First 20 Years of the Heart-Lung Machine" is a secondary source written by Denton A. Cooley. Cooley is a heart surgeon. He became famous when successfully implanted an artificial heart. He is now the surgeon-in-chief at the Texas Heart Institute. "John H. Gibbon" describes experiments pertaining to the heart-lung machine, provides valuable pictures of the heart-lung machine, and discusses the history of artificial circulation.

5. Klaidman, Stephan. *Saving the Heart: The Battle to Conquer Coronary Disease*. New York: Oxford University Press, 2000.

Saving the Heart: The Battle to Conquer Coronary Disease, written by Stephan Klaidman, is a secondary source. Klaidman was an editor and reporter for the *New York Times* and has written multiple books pertaining to coronary medicine. *Saving the Heart* describes Gibbon's attempts to create a successful heart-lung machine, Gibbon's struggles while preparing the machine for use on humans, and alternative methods of making the heart operable.

6. Koch, David H. "Pioneers of Heart Surgery." NOVA. Accessed October 1, 2011. Last modified April 8, 2011. <http://www.pbs.org/wgbh/nova/body/pioneers-heart-surgery.html>.

"Pioneers of Heart Surgery" is a secondary source written by David H Koch. Koch is a chemical engineer and philanthropist in Manhattan, New York. "Pioneers of Heart Surgery" provided useful information pertaining to the many influences on heart surgery. It also provided information about the legacy of the heart-lung machine, including many modern uses and concepts that have come to be because of the heart-lung machine. "Pioneers of Heart Surgery" discusses the importance of cyclosporin, and immuno-suppressant, in conjunction with the body's ability to accept new organs.

7. Kurusz, Mark, and Joseph B Zwischenberger. "Percutaneous Cardiopulmonary Bypass for Cardiac Emergencies." *Cardiothoracic Surgery*.

"Percutaneous Cardiopulmonary Bypass for Cardiac Emergencies" is a secondary source written by Mark Kurusz and Joseph B Zwischenberger. This source is also produced through Department of Surgery, Division of Cardiothoracic Surgery, The University of Texas Medical Branch, in Galveston, Texas. "Percutaneous" provides information pertaining to the factual aspects of the heart-lung machine. It states, among other points, that the heart-lung machine's invention was invented by Dr. John Gibbon because he wanted to find a new way to perform cardiac surgery. This article also discussed the evolution of the heart-lung machine and its increased portability.

8. Melrose, D.G. "Types of Heart-Lung Machines Used in Extra-Corporeal Circulation." *Postgraduate Medical* 37 (1961): 639.

"Types of Heart-Lung Machines Used in Extra-Corporeal Circulation" is a secondary source written by D.G. Melrose. Melrose is on the Department of Surgery at Oxford. He is a post-graduate from the Medical School of London. "Types of Heart-Lung Machines" provides information about surgeons and their increased ability to aid patients with internal heart defects while the patient's heart was cooler or stopped. This provides information connecting the heart-lung machine and its continuing effects on cardiopulmonary surgeons.

9. Miller, Kelli A. "The Invention of the Heart-Lung Machine Launches the Era of Open-Heart Surgery." In *Gale Virtual Reference Library*. 2001. Accessed October 1, 2011. Last modified 2001.

"The Inventions of the Heart-Lung Machine Launches the Era of Open-Heart Surgery" is a secondary source written by Kelli A. Miller. This source is a database source from the *Gale Virtual Reference Library*. "The Invention of the Heart-Lung Machine" provides information pertaining to the formation and ideas of the heart-lung machine. It also discusses the impact of the heart-lung machine on heart surgery and current modifications made to the heart-lung machine. Because the impact of the heart-lung machine on heart surgery is far-reaching, this article provides additional information, such as organ transplants.

10. Rodriguez-Cruz, Edwin, and Stuart Berger. "Extracorporeal Membrane Oxygenation." Medscape Reference. Accessed November 4, 2011. Last modified March 29, 2011. <http://emedicine.medscape.com/article/1818617-overview>.

"Extracorporeal Membrane Oxygenation" is a secondary source written by Edwin Rodriguez-Cruz and Stuart Berger. Edwin Rodriguez-Cruz and Stuart Berger have written a multitude of books together. Rodriguez-Cruz is a cardiologist and Berger studied pediatric heart disease. "Extracorporeal Membrane Oxygenation" provides information pertaining to the Mayo-Gibbon device and atrial septal defects. Because of its inclusion of information about the heart-lung machine, the Mayo-Gibbon device, and arterial septal defects, "Extracorporeal Membrane Oxygenation" allows the reader to make connections between all three topics.