INVENTIONS THAT CHANGED HISTORY

An electronic book on the history of technology written by the Class of 2010

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Chapter 1

The Printing Press

The History of the Printing Press

Throughout the past 4000 years, record keeping has been an integral part of human civilization. Record keeping, which allows humans to store information physically for later thought, has advanced with technology. Improvements in material science improved the writing surface of records, improvements with ink increased the durability of records, and printing technology increased the speed of recording. One such printing technology is the printing press, an invention that allowed mass production of text for the first time. The printing press has influenced human communication, religion, and psychology in numerous ways.

The printing press was invented by Johannes Gensfleisch zur Laden zum Gutenberg, born to a wealthy merchant family in 1398 in the German city of Mainz. He studied at the University of Erfurt in 1419. Later in his life, in 1448, using a loan from his brother-in-law Arnold Gelthus, he began developing a moveable type printing press. By 1450, the Gutenberg printing press was in full operation printing German poems. With the financial aid of Johann Fust, Gutenberg published his 1282 page Bible with 42 lines per page. This bible, more commonly known as the Gutenberg Bible, was considered the first mass-produced book in history because 180 copies were printed. (―Gutenberg, Johann,” n.d., para. 1-4).

The printing press was first brought to England by William Caxton. In 1469, Caxton learned how to use the press in order to sell books to the English nobility. The first book he printed, his own translation of the History of Troy, had great success and enabled him to craft his own printing press in Michaelmas, England in 1476. The first piece of English printing, A Letter of Indulgence by John Sant, was printed with this press, thus ushering in a new era for English literature.

Printing technology was brought to America almost two centuries later. British settlers often established printing presses to provide spiritual texts for colonists; thus, it is no surprise that a printing press was brought to Cambridge, Massachusetts in 1638. Printers often produced their own paper using the same techniques that were used in England. In 1690, William Rittenhouse (Rittenhausen), a German printer who learned fine Dutch paper making practices, revolutionized American printing when he established the first American paper mill in Germantown, Pennsylvania. Printers now had access to cheaper paper and had more time to work on their trade (On printing in America, n.d., para. 3).

Even after the news of Gutenberg’s invention spread to other European countries, people did not adapt quickly to the new printing style. In the fifteenth century, literacy was confined to a small elite group that was wealthier than others. With a small percentage of people who could read, the demand for books was relatively small. The practice of hand-copying books, which was done for centuries by monks and scalars, produced a very low output of expensive books with many mistakes. Still, the early printing press was slower and more expensive than hand-copying;
therefore, written word was preferred as a relatively cheap, portable, and rapid method of storing and transmitting information (Volti, n.d., para. 1-6).

Basic Science and Technology

The printing press clearly relies on a medium that allows the printer to record using ink. Dating back to 15,000 B.C.E., humans have recorded on surfaces such as cave walls, tree bark, stone, clay, wood, wax, metal, papyrus, vellum, and parchment, and paper. However, printers were constantly searching for new materials because many of these surfaces were not sufficient. For example, cave paintings, in which pictures were drawn on cave walls, were impossible to transport and difficult to see without light. Papyrus (compressed sheets of Egyptian reed stalk), as well as vellum and parchment (the prepared skin of cow, lamb, goat, and sheep), were high in cost and deteriorated quickly. Clay, which dries fast, was difficult to use (“Paper,” n.d., para. 1).

At the end of the seventeenth century, it was necessary that printers begin exploring other sources of paper because the worldwide production of paper lagged behind the capability of the printing press. Previous to this time, the methods to produce paper were very similar to the methods used in ancient China because paper producing technology was adequate for the demand. When the printing press became popular in colonial America, the mass production of newspapers led to paper shortage. In order to remedy this problem, linens from mummy wrappings were imported from the East. Mummy wrappings and rags were mixed and turned into pulp to create mummy paper. On average, the linens from a single mummy could supply two average seventeenth century Americans for a year. Although this source nullified the scarcity of paper, it had non-ideal qualities such as brown discoloration, oils, and botanical residue; in addition, this source angered archeologists and decreased in supply (Wolfe, 2004, paras. 1-3).

The most effective paper is made from pulped plant fiber. Originating from China in 105 A.D., plant fiber from the mulberry tree was used to make paper (“Paper,” n.d., para. 2). When the process spread to Europe from the Arabs in the sixteenth century, Europeans used the pulp of cotton and linen rags because they were available in large quantities. Although these people used different materials than the Chinese, the cloth was turned into a pulp and made into paper using a method similar to the ancient Chinese method. Beginning in 1850, paper producers began to use wood as the primary source of plant fiber because it was abundant. However, wood grinders at the time were not effective enough to produce pulp: there were often solid chunks of wood which led to low quality paper. On the other hand, the quality of wood pulp paper was still better than the quality of rag pulp paper. As grinding machines advanced, the practice of manufacturing wood pulp paper became more refined and efficient. In modern times, most paper mills grind wood into pulp and then apply a chemical process that uses steam along with sodium hydroxide ($\text{NaOH}$) and sodium sulfide ($\text{Na}_2\text{SO}_3$) to digest the wood chips to produce a finer pulp (“Paper,” n.d., para. 7).

As the population became more literate and the newspaper became more popular into mid-eighteenth century, the demand for printed material skyrocketed. Printers could now make more money by printing faster. Because the population was interested in current news, there was a need for printers to devise a technique to print the news faster. The first breakthrough came in 1812 when Friedrich Koenig and Friedrich Bauer invented the steam-powered press. This press
was able to print 1,100 newspapers per hour, approximately four times the speed of manual presses. The greatest printing press improvement came from Richard Hoe in 1847 when he engineered a rotary printing press. Instead of laying movable type on a flat bed, the type was set onto the outside of a large cylinder. Paper was then placed on a flat bed. When the cylinder was rotated, paper would feed into the machine with high pressure between the flat bed and cylinder, thus allowing contact for the ink to be imprinted onto the paper. This invention further improved the press, called the Hoe press or lightning press, by adding another cylinder. In addition, using even more cylinders, Hoe devised a machine that could print on both sides of a continuous piece of paper patented by France's Nicholas Louis Robert in 1798.

Language is another important consideration to printing. Printers who used moveable type printing presses had to hand lay each letter that they wanted to print; thus, the printer needed to cast each letter to be able to print. Moreover, the same letter was often used multiple times for each press indicating that it is necessary to cast many of the same letters. A language with more letters, such as Chinese, requires a vaster base set of letters compared to a language such as English. Movable type for languages that have fewer letters is easier to replace and manufacture. In countries such as China, hand-copying was much more effective than the printing press until the press became much more advanced (Printing, 2009, Original letterpress plates section, para. 3).

Impact of the Printing Press on History

The printing press influenced communication in numerous ways. Before the printing press, explorers could only record manually. Because it was very expensive to have many books copied, maps were very scarce; therefore, the information discovered by mapmakers was not used often. When it became cheaper to print, explorers were able to share their information with others, thus allowing increased education and easier navigation. The printing press also allowed scientists of all fields to compare their findings with others. Scientific theories started to form on a large scale because more supportive evidence was accessible. In mathematics, a field which relies heavily on uniform systems, mathematicians were able to build upon other works as they became available. All people were able to educate themselves better with more accessible and affordable text. Also, scientists were able to spend more time thinking about scientific concepts and less time copying previous research. The printing press clearly influenced communication (Volti, n.d., para. 1-3).

Religion was impacted by the printing press in several ways. As the amount of written communication increased, ideas spread easily. Religious ideas were no exception. Martin Luther, the leader of the protestant reformation, utilized print technology in order to spread his views. The Christian church had no control over the spread of such religious ideas. To halt the spread of these ideas, the Church would have to bring to a standstill the production of all printing presses. However, this would mean halting the printing of the Bible, a message that the Church did not want to send. In order to read the Bible, many people became literate. It is evident that the printing press affected religious movements (Volti, n.d., para. 7-9).
The printing press has influenced psychology in several major ways. Before the printing press, people were apt to believe that the text they were reading was true because only the most noteworthy information was recorded. Since the printing press became popular at the end of the eighteenth century, everything from medical textbooks to treaties on astrology were widely distributed. With so much original research circulating, it is no surprise that much of it was contradictory. People became less willing to accept the judgment of a single individual or a group of individuals. As a result, a more critical approach to understanding emerged. The printing of newspapers also impacted the psychology of people worldwide. The farther away that a reader was to a newspaper printing business, which were often located in cities, the more time it would take to get a newspaper. When newspapers first came out, travel was relatively slow; thus, it took even longer to get a newspaper. People lived closer to cities in order to improve their access to newspapers. Thus, urbanization increased. In addition, a culture based on print media was more individualistic than a culture based on collective means of communication. Because the printing press caused a movement away from the church, people had less collective communication and more individual thought. The printing press brought about fundamental change in the psychology of educated people (Volti, n.d., para. 4).

Extensions and Future Applications of the Printing Press

The printing press will likely not be improved upon or used in the future. Although advancements have been made to the printing press, modern printers are more reliable, more durable, faster, and easier to use than printing press. In addition, computers eliminate the need to physically set movable type into position; also, written text can be edited much easier with a computer. As the capabilities of hard disk storage and of the computer improve, the need to physically store information will be eliminated and replaced by electronic storage. Because improvements have been made for every aspect of the printing press, designs of various printing presses will have no use in the future.

The printing press impacted and influenced the human environment in numerous ways that made possible communication and the spread of ideas. The use of the printing press also inspired millions to become literate. Gutenberg’s invention facilitated the change of writing from record keeping to communication. Similar forms of communication will continue to affect human psychology globally.

Literature Cited


Chapter 2

Magnifying Lenses

Introduction

Magnification may be a primitive base technology, but it has become increasingly complex and useful to society. In 1292, Roger Bacon cited the potential use of magnifying lenses to aid weak eyes (Lewis, 1997, para. 3). Today, they are used in astronomy, microbiology, warfare, archaeology, paleontology, ornithology, surgery, and numerous other fields. Even though the magnifying lens is a simple concept, its current and future applications are incredibly elaborate and practical. In addition to currently being used in several areas of science, magnification has also had a significant impact on history.

Lenses and Astronomy

A magnifying lens consists of two pieces of glass. Each circular glass is thinner on the outer edges and thickens as they approach the center. As light passes through the lens, it is producing a magnified image of the object. However, a magnifying lens will only make an object appear larger if the distance is small enough. If the distance between the lens and the object is greater than the focal length of the glass, then the object will then appear smaller (Doherty, 2009, para. 4). If a magnifying lens is “2X”, then the image seen is two times larger than the actual object.

The field of astronomy has drastically changed since the application of the magnifying lens. Perhaps the most famous telescope is the Hubble Space Telescope (HST), but there are dozens of other famous telescopes that utilize magnification as well. For example, the Victor Blanco telescope in Cerro Paranal, Chile which was used to discover evidence of dark matter and dark energy. In addition, astronomy and magnification have had a significant impact on knowledge about the solar system. One of the most famous uses of the telescope is that of Galileo, who identified craters on the Moon with primitive magnification (Canright, 2007, para. 1). He used evidence provided from his telescope to support his theory of a heliocentric solar system, or a solar system with planets revolving around the sun. However, Galileo is often discredited as the first scientist to use magnification in order to identify the features of the Moon. In 1609, English scientist Thomas Harriot drew impressively accurate depictions of the lunar surface for his time period (“Thomas Harriot,” 2009, para. 5).
Figure 1. Hubble Space Telescope (HST). The Hubble Space Telescope utilizes magnification in order to study the stars which are too distorted by our atmosphere to observe from the ground (Siegel, 2009).

Microscopy

Additionally, magnification has helped in the field of microbiology. Robert Hooke was particularly famous for writing *Micrographia* in 1665, a book which included specific details on creatures such as flies, insects, and plants (Hooke, 1665, p. 9). The work also contained several detailed diagrams of the organisms are included as well as descriptions. Most noted is Hooke’s identification of the cell and its walls, named due to their similarity to the small rooms in monasteries. During the 18th century, scientists overlapped two lenses in order to improve vision and remove error for light refraction.

Centuries later in 1940, the first electron microscope was demonstrated on April 20 (“Today in history”, 2008, para. 14). Developed by Ernst Ruska two years earlier, the microscope used electrons in order to improve the quality of the images (“Microscopes,” 2009, para. 10). Instead of emitting light, the microscope emits electrons on a focused area of the examined item. These electrons cause particle interference that provides a three dimensional image of the subject. Today, our knowledge of microscopic organisms and our own cells is thorough and accurate due to magnifying lenses and microscopes. With this information, scientists are able to further research with current issues such as cancer, stem cells, and other similar problems.

Warfare

However, advances in technology are not always used for the good of mankind; several magnification-related designs have been used to assist in warfare. Telescopes, also called spyglasses, have been popular in sea navigation for centuries. Lookouts, assigned to the tops of masts on traditional wooden ships, would use the spyglasses to assist in their range of vision to watch for enemies. In more recent times, these were built into both submarines and tanks so that the viewer would be shielded and less susceptible to being attacked. Satellites have been used
with both digital and optical magnification. For example, government agencies such as the National Security Agency (NSA) use satellites to observe or find potential threats. During the Cuban Missile Crisis in October 1962, magnification was used on U-2 spy planes in order to obtain evidence of Cuban weapons (“Cuban Missile Crisis,” 1997, para. 1).

Paleontology and Archaeology

Paleontologists and archeologists also use magnification for the majority of their work. Both fields require carefully removing artifacts or fossils from digging sites. As bones become fossilized, they are extremely difficult to distinguish from the surrounding rock layers. Therefore, magnification is extremely useful when paleontologists are isolating bones from earth. Similarly, archaeologists often need to be extremely cautious when digging. Ancient artifacts are extremely delicate and can easily break, but with magnification, it is easier to view digging sites and avoid damage. Additionally, archeologists often search for small objects such as coins or jewelry that are easier to identify when magnifying lenses are used.

Ornithology

Also, ornithologists regularly utilize magnification in their careers. Ornithology is the study of birds; however, studying wild birds closely is extremely difficult. Scientists must quietly wait for hours in the wild and call the birds. When the creature does approach at a distance, binoculars are used to view the birds more closely. Binoculars, a simple but useful extension on magnifying lenses, are crucial in the field of ornithology. Before he helped to discover the structure of DNA, James Watson pursued ornithology while at the University of Chicago. At the university, the bird-watching club would gather and use magnification in order to enhance our biological understanding of birds.

Surgery

Magnification can also be used to save lives; surgery would be extremely difficult to perform accurately if doctors did not have magnification. When doctors are executing procedures such as a bypass on the heart, the tools and areas focused on are extremely minute. One wrong move could destroy healthy organs, so magnification is used to enhance the doctor’s view of the surgery area. Additionally, robots used to perform surgery use features such as motion scaling and magnification to make the surgery more precise. Microsurgery is frequently used for cosmetic surgery; however, it can also be used to perform reconstructive or infant surgery. Finally, magnification is utilized to operate by connecting fragile muscles and other tissues.

Further Uses of Magnification

One of the most well-known applications of magnification is the use of reading glasses. Reading glasses can either have plus or minus lenses; plus lenses are thickest at the center and magnify objects, and minus lenses are thinnest at the center and make objects appear smaller. Several people also suffer from astigmatism, which occurs when the viewer sees two focal points. However, this problem can be solved with a cylindrical lens. Magnification is frequently
used by jewelers to examine the quality of items such as diamonds, too. Scratches and damage are often too minute to see with the human eye and must be examined with an aid.

Impact on History

The history of the world would be incredibly different without magnification. Telescopes such as the Hubble have been extremely helpful for supporting evidence of dark matter. Due to magnification, telescopes such as the Victor Blanco in Chile can support theories with substantial evidence, as opposed to merely looking at the stars by sight. The use of scanning electron microscopes have given microbiologists a thorough understanding of particles such as cells, atoms, and other matter too small to see merely by unaided sight.

Extensions/Applications

Technology is constantly advancing, as is the application of magnification. Only twenty-eight years ago Binnig and Rohrer designed a microscope that provided three dimensional images of atomic structures (“Microscopes,” 2009, para. 11). Additionally, new telescopes are being utilized every day, such as the future replacement for the HST, the powerful and new NGST. Surgeons use magnification to be accurate when performing surgery, which is crucial.

Conclusion

Magnification has had a significant impact on history. This technology has been used in scientific areas such as astronomy, microbiology, warfare, archaeology, paleontology, ornithology, and surgery. Additionally, magnification is used every day for applications in jewelry, military, and reading. Today, it is still a prevalent technology for microbiology and surgery because of our increasing desire to understand biology beyond that which can be observed by the human eye alone.

Literature Cited


Chapter 3
Rockets

History of Rockets

Prior the invention of the rocket, life was grounded, to say the least. Cannons, artillery, and other explosive-based projectiles ruled the battlefields. The problem with these weapons was their extreme inaccuracy, requiring constant adjustment for wind, altitude, and other changing factors. The evolution of the rocket can be blamed on one historically crucial compound, black powder. First created by the Chinese over a thousand years ago, this careful blend of charcoal, sulfur, and potassium nitrate is what fuels the large explosions of fireworks, rockets, guns, and countless other pyrotechnic devices. Today, gunpowder is still made the same way the early Chinese alchemists made it. Seventy five parts potassium nitrate, fifteen parts charcoal, and ten parts sulfur are ground in large ball mills for hours at a time (Kelley, 2005, p. 23).

Around 1200 AD, the Chinese developed a method for containing their black powder that allowed them to produce the earliest forms of rockets (Bellis, 2007, para. 2). Tightly packing the powder into long cardboard tubes caused it to burn very quickly, generating large amounts of thrust. With the addition of a nozzle at the bottom of the combustion chamber, the thrust was increased even further (Bellis, 2007, para. 5). Originally used as weapons of war, Chinese rockets utilized long stabilizing sticks and relatively large explosive charges in the heads of the rockets. These so-called fire arrows were feared by all enemies. Due to their relatively simple design, they could be produced in large quantities and fired in rapid succession (Hamilton, 2001, para. 3). Between 1200 and 1600 AD, the progression of rocketry was slow at best. It was not until the mid 17th century that rocket technology began to advance. In 1650, a Polish artillery expert named Kazimierz Siemienowicz published drawings and descriptions of a multiple staged rocket, the first in written history.

Perhaps the greatest period of advancement in rocketry occurred during the lifetime of Dr. Robert Goddard. As the father of modern rocketry, Goddard’s work in the field of liquid-fueled rocketry thrusted the world into a new age (“Rocketry Pioneer”, 2009, para. 1). Growing up in central Massachusetts, he theorized about high altitude space flight early in his career. In 1912, he proposed a design for a multiple staged rocket capable of reaching the moon, but his idea was quickly shot down as being absurdly impossible. Although the idea never went anywhere, Robert did receive a US patent for his ingenious design in 1914 (“Rocketry Pioneer”, 2009, para. 5).

Goddard did not stop here, however. He went on to prove that a rocket would work in a complete vacuum, an idea that was crucial to the development of space travel. To stabilize his finless rockets, Goddard developed a gyroscopic stabilization system which kept even the most unfit-for-flight vehicle airborne (Hamilton, 2001, para. 6). By 1926, he had successfully tested and flown the first liquid-fueled rocket (“Rocketry Pioneer”, 2009, para. 2). His contributions to modern rocketry reach far beyond his development of the first flying liquid-fueled rocket.
Goddard’s creative thinking and open mind inspired others to follow his path, eventually leading to the space race in the 1960s.

The Science of Rocket Flight

Rocket flight is based on a few simple laws of physics. These are: Newton’s third law of motion, conservation of momentum, and inertia. In simple terms, Newton’s third law states that every action has an equal and opposite reaction (Brain, 2006, para. 2). In a rocket, the action is the thrust of the engine pushing down towards the ground. The reaction is the rocket accelerating in the opposite direction. Because of the law of conservation of inertia, all of the mass (in the form of tiny gas particles) leaving the burning rocket motor causes the rocket to move in the other direction (Brain, 2006, para. 3). If the rocket did not move, given enough thrust, there would be an uneven distribution of inertia, violating all laws of physics. There are two main types of rocket motors: liquid fuel and solid fuel. Solid fuel motors, such as the solid rocket boosters on space shuttles, offer much higher thrust over shorter periods of time. Liquid fuel motors provide lower thrust for much longer periods of time. Unlike a solid fuel rocket, liquid fuel motors can be extinguished and relit indefinitely. For this and other reasons, they are used in long range missiles, space vehicles, and other long-distance flying machines.

Throughout history, there has been confusion over the words rocket and missile. A rocket generally refers to a device which, after launch, is recovered using a parachute or streamer (Garber, 2002, para. 5). A missile is defined as a flying device which is not recovered. Therefore, any flying device which explodes or otherwise gets destroyed on impact is a missile, not a rocket. Around the same time that Dr. Goddard was developing liquid-fueled rockets, missiles began to be used more and more for sheer destruction. Chemists in the early 20th century began developing high explosives. Once military personnel realized how powerful these compounds were, they began strapping them to the tops of missiles. During World War I, these makeshift weapons caused an immense amount of damage (Bellis, 2005, para. 6).

Rockets in World War II

World War II marked the pinnacle of the world of rocketry. In 1932, a man named Wernher von Braun was hired by the German military to develop a mid-long range surface to surface missile (Bellis, 2005, para. 2). Von Braun and his team developed the A-2 rocket. While a very crude prototype, it was successful enough for the German military to continue granting von Braun money. The A-3 was an even greater improvement, but still was not fit for military use. In 1944, the first V-2 designed for military use was launched against London (Bellis, 2005, para. 8). Von Braun noted that “everything worked perfectly, other than the rocket landing on the wrong planet.” (Bellis, 2005, para. 9) Known and feared around the world, the V-2 rocket stood 46 feet tall and flew at over 3,500 miles per hour. It was by far the most successful surface to surface missile during the 1940s. But von Braun had more up his sleeve. When the German military realized that von Braun’s plans were spiraling out of control, they quickly took action against him. Von Braun was arrested by the German SS and Gestapo for crimes against his
country when he said he would build rockets capable of travelling around the planet and even to the moon.

NASA and the Space Race

By the mid 1950s, the world had been well exposed to the destructive forces of military missiles. It was at this point that people began to see the scientific uses of rockets as well. In 1958, the United States founded the National Aeronautics and Space Administration to “provide for research into the problems of flight within and outside the Earth's atmosphere, and for other purposes” (Garber, 2002, para. 1). One of the first goals of the new space administration was to build a successful rocket capable of lifting a large payload to the moon. The Apollo Program, which was started in 1961, had one basic goal: To land man on the moon (Garber, 2002, para. 5). On January 28, 1968, a very large and complex rocket was launched from a pad at the Kennedy Space Center in Florida. Apollo V was one of first fully successful launch vehicles, and laid the foundation for the rocket that would change the world, Saturn V. Designed in part by Wernher von Braun, Saturn V (seen in figure 1) marked a milestone in American engineering and productivity. For the first time in history, America was leading the world in science and technology, something that had not happened before.

![Image of Saturn V rocket at liftoff](image)

Figure 1. The Saturn V rocket at liftoff from the Kennedy Space Center in Florida.

Launched July 16, 1969, Apollo 11 is by far the most famous of the Apollo missions. It headed to the mood carrying commander Neil Alden Armstrong, command module pilot Michael Collins, and lunar module pilot Edwin Eugene 'Buzz' Aldrin, Jr. On July 20, Armstrong and Aldrin became the first humans to land on the Moon, while Collins orbited above
At this point, rocket technology had progressed so much that the only commonality between the Chinese fire arrows and Saturn V was Newton’s third law. Once again, we see that everything in our world is ruled by basic physical principles.

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Chapter 4
Submarines

Introduction

Picture a world in which the Titanic had never been recovered. Imagine a world in which nuclear warfare was still a thing of the future and the Marianas Trench had never been explored. All of these things would still be the works of science fiction novels had it not been for the invention of submarines. As early as the 1500s, submarines were already being conjured up in the some of the most famous minds of the time, including Leonardo DaVinci. Even today submarines continue to evolve into monstrous machines designed to help, hurt, and explore.

Innovators and Inventors

While the inventor of the first submarine is generally not a disputed subject, who designed the first one is often an area of great controversy. While some historians attribute the feat to Leonardo DaVinci, others say actual designs and discussions surfaced as early as 332 B.C. when Aristotle wrote about the so-called underwater submersibles Alexander the Great used during war (Some Submarine History, 2008, para.1). Although DaVinci briefly discussed submarines in his journals while working as a military engineer for the Duke of Milan, no serious discussion of submarines was recorded until 1578, when a British mathematician named William Bourne gained an interest in naval studies (“William Bourne [mathematician]”, n.d., para. 1).

William Bourne was born in 1535 in England (“William Bourne [mathematician]”, n.d., para. 1). He was a mathematician, innkeeper, and a member of the Royal Navy, and is famous for writing the first fully English navigational text, A Regiment for the Sea (“William Bourne [mathematician]”, n.d., para. 1). His design for a submarine, which was published in his book, Inventions and Devices, was the first thoroughly recorded plan for a submersible vehicle (“William Bourne [mathematician]”, n.d., para. 2). Bourne’s idea consisted of a wooden vehicle, covered in waterproof leather, which would be hand-rowed. This design was later used by Cornelius Drebbel, a Dutchman accredited with building the first submarine (“William Bourne [mathematician]”, n.d., para. 2).

Early Models

While working as an inventor for James I of England, Drebbel invented the submarine (Cornelius Drebbel: Inventor of the Submarine, 2006, para. 2). It was a rather primitive submarine, consisting of little more than a row boat that had been boarded over. It operated at a depth of about fifteen feet and made its first journey down the Thames River. The boat was designed to have neutral buoyancy and was hand-rowed. When rowing ceased, the boat would ascend (Cornelius Drebbel: Inventor of the Submarine, 2006, para. 2). After Drebbel’s initial design, interest in submarines began to grow. By 1727, there were already 14 different patents (Sheve, n.d., pp. 2).
The first military submarine, *The Turtle*, was built in 1775 by an American named David Bushnell (Sheve, n.d., p. 2). While the purpose of the submarine was originally to attach an explosive to enemy ships, this strategy was flawed and the submarine proved to be of little use in the war. In the American Revolution, and for much of the early 19th century, the main purpose of submarines was to attach explosives to enemy ships. This goal was rarely reached, however, because submarines had to be hand-cranked and were unable to catch up to the much more efficient warships (Sheve, n.d., p. 2).

The second American submarine, the *Alligator*, was constructed by a member of the Union during the Civil War (Drye, 2004, para.3). The inventor, Brutus de Villeroi, was a Frenchman extremely ahead of the times. He was a self-proclaimed genius, and the *Alligator* was not his only influential idea of the time. Unfortunately, shortly after time birth of the submarine it was caught in a storm off the coast of North Carolina and was has still not been found (Drye, 2004, para.3).

![David Bushnell’s original submarine design](image-url)


**Advancements Leading Up to the Cold War**

After the Civil War, many innovations in submarine technology began to occur. Battery and diesel-powered submarines were invented and in the late 19th century the first steam-powered submarine, the *Ictineo II*, was launched (Sheve, n.d., p. 3). It was invented by a
Spaniard named Narcis Monturiol and laid the foundation for nuclear submarines (Sheve, n.d., p. 3).

In the early 20th century, American engineers began to focus their efforts on making submarines for defense rather than warfare. Engineers worked towards increasing submarine efficiency and improving designs (Sheve, n.d., p. 3). During this period of advancements, the major goal was inventing a diesel-electric hybrid submarine. Unlike previous submarines, which used the same fuel source above and below the water, hybrid submarines were designed to be powered by diesel engines above the surface and by electricity below (Sheve, n.d., p. 3). This was popular with many naval personal because it helped to keep the air in submarines cleaner for a longer period of time.

Before World War I, American submarines lacked speed. During the time between WWI and WWII, U.S. engineers strove to improve their submarine fleet. Eventually they were able to increase submarine speed, making it possible for them to keep up with and thus protect U.S. warships during the Second World War (Sheve, n.d., p. 3).

While many countries were helping to pave the way for future submarines, one country in particular fronted the movement. German U-boats, invented by the Nazis, were some of the most advanced submersibles of the time. They comprised streamlined hulls, which provided increased speed, and snorkels, which removed stale and hazardous air and allowed the boats to remain submerged even while diesel engines were running (Sheve, n.d., p. 3).

Nuclear Submarines

On January 21, 1954, the U.S. launched the first nuclear submarine, the Nautilus (Sheve, n.d., p. 4). The Nautilus has many benefits that previous submarines did not, including the ability to travel almost anywhere and stay underwater for a long period of time. The Nautilus was also had a different design from previous submarines and had the capability of staying submerged for whole trips while others had been designed with the ability to only dive on occasion (Sheve, n.d., p. 4). The evolution of the nuclear submarine led to an increase in not only naval purposes for submarines, but also in travel purposes. With nuclear submarines being able to travel extended distances, many people began to use them to travel the world.

On August 3rd, 1958, the Nautilus became the first submarine to ever complete a voyage to the North Pole (Sheve, n.d., p. 4). The capability of American submarines traveling virtually anywhere coerced many other nations to search for advancements for their own submarines. Nations like the Soviet Union began to construct new submersibles with the goal that they would be able to keep up with the U.S. Unfortunately, many of the Soviet’s initial attempts resulted in defective submarines and fatal accidents. Even though most of the world was making steps toward perfected nuclear submarines, the Soviet Union continued to produce diesel-electric submarines (Sheve, n.d., p. 4).

Shortly after the invention of the nuclear submarine, Navy personnel began to search for weapons to arm which could be used to arm the ships. As a result, in 1960 (during the Cold War) the submarine George Washington was launched with the first nuclear missiles (Sheve, n.d., p. 5). The U.S. navy engineered two different types of nuclear submarines: the Fleet Ballistic Missile Submarine and the Attack Submarine. The Fleet Ballistic Missile Submarine (SSBN), nicknamed “boomer”, was designed to launch missiles at other nations. In contrast, the Attack Submarine, (SSN) or “fast attack”, was designed with the ability to attack rapidly other ships (Sheve, n.d., p. 5). Because the SSNs were built mainly for speed and stealth, they were only a little more than half the length of the SSBN submarines (Sheve, n.d., p. 5).

Submarines in the Cold War

Starting in 1947 at the commencement of the Cold War, submarines began to grow exponentially in popularity. Both American and Soviet forces strove to design the most advanced submarine of the time. Three main types of submarine were developed, the first of which was the SSBN. This typed proved to be the most important to the Cold War because they were essentially untouchable. SSBNs were capable of moving practically anywhere and were thus very hard to track (Sheve, n.d., p. 5). This proved to be a necessity to both sides and soon SSBNs were a common occurrence.

Although not the first to be developed, the SSN, or “fast attack” submarine, was the most common of the time (Sheve, n.d., p. 5). These were specifically designed for speed and stealth and could easily obliterate any enemy ship, making them especially useful for offensive attacks.
SSNs were also designed with the capability to track other submarines and ships (Sheve, n.d., p. 5).

The third model of submarine developed during that time period was one designed to transfer special operations teams in and out of enemy terrain. These submarines, which are still very popular today, were built in a manner which makes them ideal for spying on foreign activity, transporting naval personnel, and participating in naval war training activities (Sheve, n.d., p. 5).

Since the Cold War, four more nations, including France and China, have joined the U.S. and Russia in the nuclear submarine movement (Sheve, n.d., p. 5). Other countries are currently trying to create nuclear submarine programs as well. With people all over the world constantly making technological advancements, it is almost impossible to say what the coming years will bring. Naval technology is a constantly growing field and submarines continue to improve all the time. They are even being used in non-naval expeditions. For example, students at Tel Aviv University, led by Dr. Dan Peer, have recently engineered a small biological submarine to eradicate cancer cells in infected human bodies (Tel Aviv University, 2009, para. 3). The team hopes to get the small device, made from all organic substances, functioning within the next three years. As evident by this, submarines are in no way limited to the oceans.

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Chapter 5

Photography

Introduction

Photography, which is the process of creating pictures by capturing a still image of a moment in time, has developed and advanced since the early 19th century when the subject was first explored. Cameras are used when taking photographs, and many people enjoy taking pictures which allow them to convert abstract memories into concrete forms. In our world now, people consider cameras as electronic devices that use energy to operate, but the only necessary components of cameras are film, a small opening in which light can pass through, and a light-proof container.

History

The history of photography dates back to roughly 200 years ago. The first photograph was taken in 1816 when Nicephore Niepce placed a sheet of paper coated with silver salts in a camera obscura (“Invention of Photography,” n.d., para. 1-2). Primarily used as a tool to help people draw and trace images, this camera obscura, which was a box with a hole on one side, was the first device used for photography. The special paper that was inserted in the box produced a negative photograph because silver salts where known to darken when exposed to light. Although the colors were inverted, Niepce succeeded in capturing a still image using sources from nature. But as soon as he took the film out of the box, the whole paper blackened.

After Niepce passed away, his friend Louis-Jacques-Mandé Daguerre took over his studies. In 1839, Daguerre invented a new direct-positive process called the daguerreotype, which took both time and labor. Preparing the film was a tedious procedure because the plate needed to be polished and sensitized in complete darkness. The exposure time, which was approximately 3 to 15 minutes, was lengthy and unfeasible for a photograph (“The Daguerreotype,” 2002, para. 1). The photograph was developed over mercury after being exposed to light.

At around the same time, William Henry Talbot was also researching photography. His invention called the calotype process was a negative process and was patented in 1841. The base material used for making the calotype negative was writing paper, which was soaked in a silver nitrate solution and a potassium iodide solution and dried each time. It was then soaked in a gallo-nitrate solution that was prepared right before inserting the film into the camera. The photographer had to repeat the same process after exposure, which was mostly around a minute, to develop the photograph (“The Calotype Process”, n.d., para. 3).

The cyanotype process invented by Sir John Herschel in 1842 was economical and is known for its unique blue hue. In this process, he placed a negative and a piece of paper with iron salt (ammonium citrate and potassium ferricyanide) layers under the sun. A positive image then appeared on the paper, which he then washed with water (“Historic Photographic Processes”, n.d., para.2).
Because preparing and developing the plates was a complicated process, George Eastman invented dry film in 1888. No liquid solution was necessary after taking the picture, which led him to making roll up film. This also eliminated the need to change the plate each time a picture was taken. He also created the Kodak camera which was the first portable picture taking device (“Hall of Fame”, n.d., para. 2).

All photographs were monotone until James Clerk Maxwell invented the trichromatic process. While studying color blindness, Maxwell introduced the first color photograph. By using only green, red, and blue filters, he created many different colors (“James Clerk Maxwell”, n.d., para. 3). This process was the foundation of our color photography that exists today.

Types of Cameras

The earliest type of camera is a pinhole camera, which consists of a light proof box, a film, and a hole on a side of the box. When one looks through the small pinhole, he or she can observe the scene, but it is inverted and reversed. The hole is the substitution for a lens in a modern camera. The difference between a lens and a pinhole is that because a lens can let more light in compared to a small hole, the film takes a shorter amount of time to process (“How does a pinhole camera work?,” 2000, para. 3). The pinhole compresses the image into one small point to make the scene sharp and crisp. The film, which is located on the other side of the hole, records the image. The pinhole camera is very similar to the camera obscura.

For any camera to operate (except a digital camera), photographers needed to prepare film. As described previously, scientists used the chemistry behind light sensitive compounds (mostly silver compounds) to manufacture films. The roll of film that is now used record images due to chemical change. The reaction is caused because photons are contained in light, and the energy of photons is related to the wavelength of light. For example, red light only has a small amount of energy/photon and blue light has the most amount of energy/photon. The base of the film is in the middle of a roll of film (about 0.025 mm) and is made out of thin transparent plastic material (celluloid). On the other side, there are 20 or more layers each less than 0.0001 inch thick which gelatin holds together.

Some layers are only used for filtering light or controlling the chemical reactions when processing. The layers used to make images contain very small pieces of silver-halide (mix of silver-nitrate and halide salts (chloride, bromide, or iodide), and are created with subtle variations in sizes, shapes, and compositions. They detect photons and react to electromagnetic radiation (light), and organic molecules called spectral sensitizers are applied on the surface of the grains to amplify their sensitivity to blue, green, and red light. These multiple layers each have a different function in the single film.

Because in the late 19th century photographers were not able to be in a picture without using an air pressure tube connected to the camera that operated as a shutter, Benjamin Slocum
invented the self timer. He incorporated pistons, springs, fire, and fuse to control the time it takes to compress the air inside the cylinder in which the parts were all contained (Slocum, 1901, p. 4). The compressed air then triggered the shutter allowing photographers to set the timer and be in the picture.

Currently most people have abandoned cameras that need film because the development process is tedious. Also, because many people use their computers more often and it is easier to organize the many photographs that are on the camera, they prefer to use digital cameras. Compared to having to take a finished roll of film to a place that develops it and picking it up after a couple of days, connecting the camera to a USB port and transferring the files saves time. Moreover, having a digital camera means that the photographer can check the picture immediately to see if the result is satisfactory.

Digital cameras require electricity but do not need film like the cameras that were used in the past. Instead they use a semiconductor device, which is a plate with multiple square cells called a Bayer filter. Each cell filter is red, green, or blue and there are twice as many green filters to mimic the human eye, which detects green light more than the other two colors. The light that passes through these filters is converted into electrons and recorded electronically. Because the Bayer filter also passes infrared light, which is not in the visible spectrum, there is another filter inside the camera called a hot mirror that blocks the unnecessary light (Twede, n.d., para. 4).

The Bayer Filter (Twede, n.d., para. 5) There are twice as many green cells than the red or blue cells. These filters only let in light in their own spectrum. For example, red light will only pass through the red filter.
There are multiple photographic terms that are necessary when taking professional photos. The shutter speed is the amount of time the shutter is opened. It can range from 1/8000 of a second to as long as 30 seconds. By changing the shutter speed, photographers can adjust the amount of light that the photograph captures. Also, when taking a picture of a moving object, by quickening the shutter speed, the picture can become crisper without being blurry.

The aperture is a hole inside the lens in which light passes through before reaching the shutter. The size of the aperture can be changed and is usually expressed in “f-stop” or “f-numbers”. The aperture and the f-stop are inversely related, and when the f-stop is small, the aperture is large. By changing the aperture, people can control which part of the picture is sharp and crisp, and which part of the picture is blurred. By reducing the size of the aperture opening, everything from a foot away to a mile far can all be in focus because the light is condensed at a smaller point. Both shutter speed and aperture can be varied to control the lighting, for example, the camera can be set to have a wide aperture for a short amount of time, or a small aperture and a long shutter speed (Mackie, 2006, para. 6-17).

Modern Applications

Photography has advocated many areas of study since cameras were invented. One of the most important roles of photographs is that it is used as evidence in crime scenes. Because photographs are accurate and do not represent artificial information, it is the strongest witness that can exist. There is no perfect way to distinguish if a person is telling the truth when claiming to be the witness, but photographs are unaffected by human emotion and therefore authentic. Forensic photography is the special branch of photography used for documenting crime scenes. Usually, the items are placed on top of a seamless background before being photographed. Forensic photographers must be careful about lighting so that shadows do not obstruct important pieces of evidence. They magnify certain subjects such as cuts or blood stains, and constantly take pictures of a subject if it is undergoing a change during analysis. They also use various tools for certain instances when evidence cannot be seen with the naked eye. Certain fibers appear differently under different wavelengths, gunshot residue can be seen clearer when using infrared film, and semen becomes more visible under ultraviolet light (Mancini, n.d., para. 1-3).

Another impact photography has had on history is that it is now a crucial part of media. Photographs are used in magazines and newspapers which assist readers to understand concepts and events in the article. In addition, photography was the foundation for video recording which is the basis of news, television shows, and movies. People now have a better knowledge of things they cannot actually see in real life because of the photographs and videos. They know what life is like in the rainforest, although they have never been there, because of the images.
Photographs are also vital in the medical field. The pictures that medical photographers take must not have excess detail which may confuse the viewer, but needs to be clear as they will be used for analysis and investigation. These photographers usually take pictures of tissue slides, bacterial specimens, and laboratory settings. Some of them will be used for education and may appear in textbooks, science magazines, and medical presentations (Larsson, n.d., para. 6). X-rays, another concept used in the medical photography, is a type of electromagnetic radiation. The invention of x-ray machines has greatly helped doctors determine the problems inside a person’s body. The photons emitted by these machines do not pass through dense material, such as bones and teeth, making them appear white on the film. They can also be used to detect tuberculosis, pneumonia, kidney stones, and intestinal obstruction.

Furthermore, pictures play a great role in keeping memories. Before cameras were invented, people used to have portraits drawn. This took a very long time considering the fact the person being drawn had to stay still for long hours until the painting was done. But because photography was invented, it is now both easier and quicker to obtain a beautiful portrait. Also, now that a majority of people have hand held cameras, they are able to carry them everywhere and snap shots of the places they visit and the scenes they see. Pictures last forever, and do not deteriorate like memory does.

Many pictures of war and photojournalism have also contributed to our world. They are an “expression of the ideology, technology, governmental policy and moral temper of a particular point in history” (Winn, 2005, para. 4). Pictures clarified the truth and annulled propaganda. Also, the families that waited for their loved ones who departed for war were able to remember them by keeping a portrait. In addition, pictures of the actual battle field helped express the gravity of war and reminded individuals of the significance of world peace. Although new generations have not experienced war, by looking at the pictures in museums and books, they can better understand how cruel battles are.

Conclusion

The innovation of photography has greatly changed out world in multiple ways. The history of photography dates back to a couple hundred years ago, but the idea of producing images using chemistry had existed many centuries before then. Without photography, science would not have been able to advance so quickly, and people would not have been able to comprehend what it is like in foreign regions. We should be grateful to the inventors of photography as they have contributed greatly to our society.
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Chapter 6

DDT

Introduction

Stockholm, Sweden, 1948: Professor G. Fischer stands on the stage, touting the use of the new wonder-pesticide, DDT. One can only imagine his excitement, his charisma, as he gives this presentation speech for the 1948 Nobel Prize in Physiology or Medicine. This pesticide has saved countless lives, he says it has allowed us to control an outbreak of typhus in winter, a previously unheard-of feat. It has virtually eliminated malaria when tested in marshes. And then, he tells a short anecdote about an army major who had his window treated with the pesticide to get rid of flies. The day after the window was thoroughly cleaned, flies were still being killed on contact with the glass. This, he said, was one of the greatest qualities of DDT, it had great environmental persistence. Only a very small dosage was required to kill insects and that small dosage, once applied, would not get washed away or break down over time (Fischer, 1948, para. 2-3, 9, 14). Thunderous applause ensues.

Flash forward. A woman sits alone at her desk, struggling to find the right words for her manuscript. She’s seen the effects of this poison herself. A friend sent her a letter not long ago to tell her about the dead songbirds around the family birdbath. Even though it had been scrubbed thoroughly a few days before, birds in the area were dying at an alarming rate. Elsewhere, the populations of hawks and falcons were dropping sharply. Around the US, the environment was being decimated and she needed to get the word out as best she could. The woman was Rachel Carson. Her book, *Silent Spring*. What could change in the public eye so quickly, how could anything so rapidly go from a savior to a killer? DDT has a long and messy history, filled with saved lives, yes, but also with over-use and environmental problems.

Discovery of DDT

DDT (dichloro-diphenyl-trichloroethane), would have stayed in obscurity if not for Paul Müller. Its synthesis had been published in 1874, but no use had been found for the chemical. Thus it disappeared into vast and dusty record-rooms and was not dealt with again until 1935, when Müller, inspired by the recent success of some pesticides used to treat cotton, presumably found it, blew off the metaphorical dust, and set to work killing insects. He actually only discovered the properties of DDT as an insecticide accidentally. He did test DDT on flies, but found no results during his trial. It was not until he cleaned his testing chamber to try a different pesticide, and by a fluke, ran the test longer than usual, that he noticed that the flies he was testing his chemicals on were dying. To his surprise, however, it was not his newly synthesized chemicals killing them, but instead the trace amounts of DDT left over from his first trials (“The mosquito killer”, 2001, para. 1).

Müller continued his testing and found that DDT could kill flies, lice, and mosquitoes, and he developed two DDT-based pesticides, Neocide and Gesarol. They proved wildly successful (“Paul Müller: Biography”, 1964, para. 3). Soon, people began spraying DDT-derived pesticides on wetlands and started to use them to dust soldiers and concentration camp survivors. His pesticides virtually eliminated malaria in the wetlands and efficiently killed the typhus-
carrying lice that so easily could spread through concentration camps and the military (“Paul Müller: Biography”, 1964, para. 3). In 1948, he won the Nobel Prize in Physiology or Medicine for the number of lives his pesticide had saved from the ravages of insect-borne disease.

DDT in Medicine

DDT soon eliminated malaria in the American South and Panama, making construction of the Panama canal possible. It virtually eliminated the disease in parts of Greece as well. In trials, DDT was so deadly to mosquitoes that in controlled lab tests even the control groups died. Testers realized that a few molecules of the pesticide that had been released into the air and happened to settle in the control flask. This was enough to kill all of the mosquito larvae it contained. When DDT was tested in ponds separated too far for wind to carry the pesticide among them, mosquitoes in the control groups still died because waterfowl would get the DDT on their feathers before flying to the other pond (“The mosquito killer”, 2001, para. 3).

DDT was even useful in war. Some of the Pacific islands necessary to the war were near-inaccessible because too many soldiers were contracting tropical diseases and could not fight. In Saigon, for example, before the advent of the pesticide, it was impossible to invade because soldiers were contracting dengue fever, which could keep them confined to infirmaries for up to five weeks. Planes were sent to spray DDT along the coast and the army invaded with little trouble. The close quarters of barrack life also allowed for the spread of typhus-carrying lice. During World War I, over 200,000 citizens and prisoners in Serbia alone died of typhus (Tshanz D, n.d., para. 21). By World War II, the disease was kept nearly completely under control.

The Heyday of the Wonder Pesticide

Soon, more and more people found uses for DDT. Not long after Müller discovered its properties as a pesticide, people were using it to spray crops, cattle, and residential neighborhoods. It was even added to paint in order to kill the horseflies often found in barns. Cattle treated with DDT weighed an average of fifty pounds more (Ganzel B, n.d., para. 7), and crops had a much higher yield when their pests could be virtually eliminated. When DDT became more widespread, it was simply sprayed in residential neighborhoods to eliminate the nuisance of mosquitoes. It was even sold to homeowners for use indoors.

Soon Americans had access to cheaper and more plentiful food, had far fewer nuisance insects in their homes, and could go outdoors with impunity when they otherwise would have been inundated by biting insects. Elsewhere, neighborhoods in Greece where instances of malaria included 85% of the population or more were made safe for citizens. DDT, sprayed in the air and water, efficiently killed malaria-carrying mosquitoes and instances of the disease dropped to about 5% of the population (Fischer G, 1948, para. 14). At the time, nearly 300 million people contracted malaria a year and 3 million died of it. Because DDT was so efficiently lowering rates of malaria, it was hailed as a life-saver by millions of people and as the scientific community. It was then, however, that the problems with the pesticide began to surface.
DDT and the Environment

The ecological implications of DDT were first recognized after a mass-spraying program was undertaken to control beetles carrying Dutch elm disease in 1950. Soon after the program, robins in Michigan began to die. While the pesticide was harmless to birds in small amounts, many insects, even insects unrelated to those the sprayers were targeting, would get the pesticide either on them or in their gut. Birds preyed on the DDT-covered insects, and the relatively small concentrations of the pesticide in the bodies of the insects were stored in the fatty tissues of the birds. Because the robins are predatory and have a much smaller biomass than the number of insects they consume, these small concentrations began to compound in their bodies.

Soon, they were reaching lethal doses of the pesticide. Populations of other predatory birds began to drop for the same reason, including those of bald eagles, peregrine falcons and brown pelicans (Ehrlich, Dobkin, & Wheye, 1988, para. 2, 6). DDT actually did not kill many of the larger birds, such as pelicans or hawks, directly. In larger birds, the levels of the pesticide reached poisonous levels, but it could interfere with distribution of calcium in their bodies, preventing them from depositing enough calcium carbonate in their eggshells. Because of this, their eggshells were weak and often broke before hatching. Fish were considerably more difficult to study but were very adversely affected as well (“Effects of DDT”, n.d., para. 9). As effects on the environment became more obvious, it was clear that, while the pesticide had proved so useful for control of mosquitoes, it was decimating coastal environments and bird populations. Some species, like the brown pelican, were so affected that they would likely go extinct if use of the pesticide was not discontinued.

Rachel Carson

Rachel Carson was arguably the most influential proponent of discontinuing use of DDT. Before the advent of DDT, she mainly produced brochures and radio programs for the US Bureau of Fisheries. She wrote about conservation for some magazines and newspapers and had published three books, titled Under the Sea-Wind, The Sea Around Us, and The Edge of the Sea before she learned about the ecological effects of the pesticide. One day, however, a friend from the east coast sent her a letter bemoaning the state of the local ecosystem after her neighborhood had been sprayed for mosquitoes (L. Budwig, 1993, para. 27). Robins everywhere, she wrote, were dying. Carson took notice. She began writing Silent Spring in 1958 and finished it after only four years. In it, she explained the problems with the pesticide’s environmental persistence, how it could poison beneficial insects and non-targeted animals, such as birds, and emerging research on how the pesticide could cause genetic mutations and cancer in humans.

However, she did far more than just cite facts and statistics. She composed a poetic and emotional plea to the citizens of the US, begging them to stop destroying the environment before it was decimated and there were no native mammals or birds remaining. This image was where she took the title of her book from, the thought of a spring where there were no animals hunting for food, and there was no birdsong ringing through the treetops. Her book was a political argument against use of the pesticide and she was trying to communicate the message that without the discontinuation of DDT, spring would literally be silent (“Rachel carson”, n.d., para. 5, 11)
The Aftermath of the Pesticide

The plea worked. Soon, the public took Carson's side and forced the government to follow. DDT was banned for use in the US in 1972 (“DDT ban”, 1972, para. 2). Bird populations began to recover. Robin populations were back to pre-DDT levels within a few years of its discontinuation and brown pelicans were off the endangered species list in most states about twenty years after that (Ehrlich, 1988, para. 7). However, DDT still persists in the environment in many parts of the country some bird populations still have not completely recovered, and exposure to contaminated areas is linked to several different types of cancer. However, the state of the environment has much improved since the use of the pesticide. An interesting offshoot of this near-catastrophe was that, because of the backlash involving the effect of DDT on the environment, the government passed the Endangered Species Act the next year. The act protects animals named in the national endangered species list. So, actually, through the fact that DDT was so harmful to the environment, DDT helped protect it.

Future Uses of DDT

However, DDT may not be lost forever to the dark halls of history. It is still one of the most efficient pesticides available. In places with extremely high instances of malaria, especially in Africa, where the most dangerous species of malaria carrying mosquitoes are native, world leaders and the World Health Organization are clamoring for its use (“WHO gives indoor use”, 2006, para. 1). Though it is still illegal for use in the US, it is becoming slightly more common in countries where the costs of environmental harm and increased instances of cancer are deemed far less important than the sheer number of lives that stand to be saved by eradicating malaria. As a result, DDT-treated mosquito nets are being distributed in some countries, and the pesticide is still sprayed in some areas. (“WHO gives indoor use”, 2006, para. 12).

However, this is done under the watchful eye of the governments involved, and unlike in the 1960s when use of the pesticide was completely unregulated, governments now understand the implications of its use. Additionally, DDT breaks down much more quickly in flooded soil, such as one would find in the tropical areas being treated. (Sethunathan N, 1989, pp. 5). In Africa, malaria kills nearly a million people yearly. DDT, of course, is highly efficient at killing mosquitoes. And so the story comes full circle. DDT started as a wonder-pesticide that saved millions of lives from malaria and typhus. It was then cast as an incredibly harmful force, slowly and insidiously working its way through the environment and killing everything in its path. Now we realize that, while DDT did do a lot of environmental harm in the past, it may have a legitimate use today as long as it is regulated carefully. DDT may not be an ideal solution, but it has the potential to do far more good for people.

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Chapter 7

Anesthesia

Introduction

Anesthesia is the temporary loss of sensation that is induced by drugs that interfere with how nerves communicate. Prior to the advent of modern anesthesia, surgical procedures were often avoided as much as possible. Doctors would have to endure the screams of pain as they operated on a patient, who was in a great deal of agony. To weaken the sensation of surgical incisions, alcohol, opium, and various herbal remedies were used. Sometimes the patient would be physically knocked unconscious prior to surgery. It was difficult to control the amount of anesthetic given, which posed a safety issue. Too much anesthetic can cause neurological damage, while too little is ineffective. Nowadays, thanks to technological advances, it is possible to control the dosage of anesthesia required to instate and maintain unconsciousness. It makes surgery safer while ensuring that the patient is not in any pain.

Anesthesia in Ancient History

Pain management during surgery is a struggle that humans have been facing for ages. The origins of surgical anesthesia date back to Ancient Greece and Rome. In the first century AD, the Greek physician Dioscorides recorded a number of plants that had anesthetic qualities (Keller, n.d., para. 5). Meanwhile, the use of opium and henbane as anesthetics was recorded by Dioscorides’s Roman contemporary Pliny the elder (Keller, n.d., para. 5). Hemlock, mandrake, and dwale were the most common herbal anesthetics used, but they were not very effective and eventually fell into disuse. Common operations at the time included amputations, tooth extractions, and caesarean sections. Surgery was also a treatment option for ailments such as hernias, skull injuries, tumors, severe headaches, and insanity. Surgeons were required to operate quickly while tolerating screams emitted by the patient, who would be held down by several large men.

For the most part, the anesthetics most commonly used were plants. Many of them eventually fell out of use because the availability depended on the season and quality of the farming location. Also, the risks of using these herbs were high, particularly due to problems with administration that lead to accidental overdosing. Most were deemed ineffective or too risky for common use. Opium is a potent narcotic and pain reliever that will cause nervous system failure and death if taken in excess. Its history goes back to the Roman Empire, but it was prominently used in the Middle Ages. The Babylonians were the first to discover the anesthetic properties of mandrake around 2000 BC (Keller, n.d., para. 7). Mandrake (*Mandragora*) was commonly used among Egyptians, Chinese, Assyrians, Greeks, and Hindus. The Greeks mixed it with wine before administering the anesthetic to patients. It was later determined to be a narcotic that is poisonous in copious amounts. Henbane (*Hyoscyamus*) and hemlock were used less
frequently because of its strength. Both were sleep aids. Henbane was commonly used as a local anesthetic, especially in the mouth (Keller, n.d., para. 10). Like these plants, ingesting henbane and hemlock in large quantities is toxic and lethal.

Anesthetics were often more effective when mixed together. The first recorded example of such a cocktail, called *spongia somnifera* (soporific sponge), was between the ninth and tenth centuries AD; it comprised mandrake, opium, hemlock, and henbane (Keller, n.d., para. 6). A sponge was dipped into the solution and left out to dry in the sun. Next, it was submerged in warm water, and the residue inhaled through the nostrils until the patient was unconscious. Laudanum was another type of solution which was simply opium blended with alcohol (Keller, n.d., para. 13). Alcohol was mixed with certain plants because it was ineffective alone. Dwale, which can be traced back to the 12th century AD, is a liquid concoction comprising of bile of a boar, lettuce, vinegar, bryony root, hemlock, opium, henbane, and wine. However, it is believed that opium, hemlock, and henbane were the only effective ingredients in the mixture (Keller, n.d., para. 9). Inhaling vinegar was a common practice for reversing anesthetics at the time, which proves that they were not very strong.

There were also nonconventional methods of inducing a state of unconsciousness. Getting a patient drunk before operating was one way. Prior to surgery some would be physically knocked unconscious by trained professionals. Originating in Egypt around 2500 BC, another practice was using a tourniquet, which numbed the blood vessels and nerves by placing large amounts of pressure on the affected area (Keller, n.d., para. 13). However, it was deemed ineffective and tissue damage from the device inflicted more pain than the actual surgery would have. Choking the carotid artery also temporarily ceased pain sensations, but that method was futile as well (Keller, n.d., para. 15).

**Development of Modern Anesthesia**

The quest towards modern anesthesia began in the 14th century when Raymond Lully synthesized ether from sulfuric acid and alcohol, naming it sweet vitriol. Ether made general anesthesia possible, but it was flammable and toxic. That discovery was ignored until the 16th century when Valerius Cordus reinvented ether, although his work was also overlooked. In 1773, Joseph Priestley invented nitrous oxide, a compound with similar properties as ether. Doctors were wary of experimenting with this discovery on patients at the time. Henry Hickman of Ludlow, England, was one of the first physicians to recognize the potential use of nitrous oxide and ether as anesthetics (Volti, 1999, para. 3). Sir Humphrey Davy discovered its potential use as an anesthetic during his observations of people under the so-called laughing gas at social events. He noticed that they were desensitized towards pain and proved its safety and effectiveness. However, surgeons remained wary.

In 1842, the first modern human anesthetic was used by Crawford Long while removing cysts from a young boy in Jefferson, Georgia. However, he did not publish this discovery until 7 years later, by which time other physicians and dentists were recognizing the uses of anesthesia (Volti, 1999, para. 3). Attending a play at the theater in December 1844, Horace Wells also discovered that nitrous oxide could dull pain. He used it on his dental patients; however, when he presented this discovery at Massachusetts General Hospital in Boston to a gathering of colleagues, the patient woke up during the procedure. Deeply humiliated, Wells committed
suicide several years later. His dentistry partner, William Morton, began using ether, which was stronger.

In a time where anesthetics were a popular topic of research, Henry Hill Hickman discovered suspended animation, which was an inhalant that resulted in a painless slumber. In the 1820s he deprived animal subjects of air and provided just CO2, calling it anesthesia by asphyxiation. He claimed that lack of oxygen would render the patient unconscious throughout the duration of the surgery, resulting in less bleeding and shorter recovery time. However, this idea was largely ignored.

James Young Simpson discovered another anesthetic, chloroform, in 1847. While it was potent, it was not practical, entailing extended recovery time and strong side effects. In 1884 Karl Koller found that applying cocaine topically could cause numbness, resulting in the synthesis of procaine and lidocaine, which are similar to cocaine without its toxic ramifications.

It is a common misconception that anesthesia was not used during the Civil War, but for the most part that claim is false. The only recorded instance of surgery without anesthesia was at the Battle of Iuka, where 254 patients endured surgery by either drinking whiskey or biting a bullet. However, over 80,000 surgeries were performed with anesthesia in the form of ether or chloroform; it was dripped onto a cloth and inhaled by the patient (“Civil War Surgery”, 2004, para. 17). Surgery had to be performed quickly before the patient became agitated and started moving around and screaming; he or she would often have to be held down by surgical assistants. Operations were performed in open daylight due to lack of better lighting. The myth originated when a passerby heard moaning and thought the patient was awake and in pain. This practice soon fell into disuse.

How Anesthesia Works

The purpose of anesthesia is to sedate, immobilize, and induce unconsciousness, amnesia, and inability to feel pain. Except for nitrous oxide, all general anesthetics exist in liquid form. Although the drugs vary greatly structurally, their effects are very similar. They function by absorbing into individual nerves and interfering with the movement of sodium ions. Anesthetics alter the membrane potential of cells in the brain and spinal cord, interfering with the ability of the neuron to send and receive neurotransmitters. How well an anesthetic drug reacts with a neuron depends on the exterior composition of the cell. The cerebral cortex is affected first, resulting in loss of consciousness. More anesthesia is required to affect motor functions, which are controlled by the cerebellum (Caton, 2009, para. 4). Anesthesia wears off as the body processes the chemicals. Unfortunately, at this time little is known about the specifics on how anesthesia functions in the body, but it is a popular topic of research.

Historical Impact of Anesthesia

Before anesthesia, operating theaters would be located on the top of towers and other places where people outside could not hear or see what was going on inside. Sometimes patients would run away just as their surgery was about to begin (Fenster, 1996, para. 15). The vivid pain of going under the knife permanently traumatized many patients afterwards (Fenster, 1996, para.
The number of suicides was high; many would rather take their own lives instead of undergoing operations.

Anesthesia became an important addition to the medical community once it was discovered. Surgery made great advances in the 18th century that would not have been possible without modern anesthesia. Before anesthetics, amputations were the most commonly performed procedure because they were quick. With anesthesia, surgeons could perform more complex, time-consuming operations, saving more lives. (Fenster, 1996, para. 11). As a result, more surgeries were performed.

Anesthesia found its use outside the operating theater as well. Ether was soon used in the delivery of babies, the first in 1853 when Queen Victoria gave birth to her son Leopold under the influence of anesthesia. Afterwards, Dr. John Snow made anesthesiology a medical specialty (Fenster, 1996, para. 41). In prisons it was used to subdue criminals before execution, a practice that was soon abandoned because it lessened the punishment. Criminals would commit felonies with the help of ether, temporarily intoxicating anyone in their way. In the military, doctors would administer the gas to soldiers to see if they were telling the truth about their wounds (Fenster, 1996, para. 39). Due to its popularity, it was suggested that soldiers bring bottles of chloroform to battle in case of injury. However, many deaths occurred because of accidental overdosing and improper handling of anesthetics. Since then, stricter regulations were incurred. (Fenster, 1996, para. 43).

Today general anesthesia is administered to approximately forty million people in North America each year. In some cases, using anesthesia to suppress the nervous system is more risky than the operation itself. Approximately one out of 13,000 patients dies from anesthesia-related incidents. On average, during one to two out of every thousand major operations performed under general anesthesia the patient experiences some degree of consciousness for a brief period of time (Orser, 2007, p. 56). Occasionally, afterwards a patient will remember scenes during the operation. Anesthesiologists determine the amount of medicine required for every individual patient because it is different for everyone. Too much can become lethal, while too little is ineffective. When given too little anesthetic, the patient is awake but unaware of his or her surroundings. He or she may appear to be under the influence of alcohol, experiencing drowsiness and confusion. On the other hand, excessive anesthesia impairs the body mechanisms that maintain homeostasis and shuts down basic body functions, resulting in a vegetative state.

Anesthesiologists are crucial to the surgical process because they also monitor the postoperative side effects of the drug. In older adults, delirium is common, a condition known as postoperative cognitive dysfunction (POCD). Risks of general anesthesia include nausea, irregular heartbeat, temporary delirium, and very rarely, heart attack or stroke. Respirators are used to avoid breathing complications. Local and regional anesthetics are generally safer; after an operation weakness or paralysis may be felt in the affected area. However, allergic reactions and difficulty breathing may result from any type of anesthesia. Seldom does permanent nerve damage occur.

There are different types of drugs that are used as anesthetics or are similar to anesthetics. Sedatives cause unconsciousness but do not eliminate pain. Tranquilizers relieve anxiety. Neuromuscular blocking agents obstruct nerve impulses and paralyze muscles. Narcotics
eliminate pain but do not induce the same state anesthesia does unless administered in massive amounts. Barbiturates serve as intravenous anesthetics.

The Future of Anesthesiology

The effects of anesthesia can be detected on the brain using MRIs (Magnetic Resonance Imaging) and PETs (Positron Emission Tomography) machines. Many studies pertaining to anesthesia can also be used towards improving sedatives, memory drugs, and sleep aids (Orser, 2007, p. 56).

The neurotransmitter GABA (gammaaminobutyric acid) is currently a popular topic for research because it inhibits the exchange of other neurotransmitters between neurons (Orser, 2007, p. 57). The effects of GABA are magnified by the use of anesthetic drugs. GABA alters the electric potential of the neuron, rendering it negatively charged and impairing its ability to fire neurotransmitters. A study conducted at the University of Pittsburgh confirmed that, in mice lacking the GABA receptor, sensitivity to anesthesia was greatly reduced (Orser, 2007, p. 60). This is just an example of how chemical interactions between anesthetics and neurons are being studied to discover how to emphasize desired effects of anesthesia while suppressing side effects.

A current issue is consciousness, usually temporary, during surgery. Studies are being performed to determine the relationship between anesthetics and level of awareness and what factors are involved. By identifying the neuron receptors involved it may be possible to tell when a patient may wake up during surgery and synthesize drugs to reduce this effect.

A patient is declared unconscious when the body does not respond to external stimuli. However, the problem is that the patient does not necessarily have to be unconscious for this to happen. Measuring the level of brain activity using EEGs (electroencephalography) during surgery may be an option to determine consciousness during an operation. However, it is not completely reliable because it is possible for a person to be alert but have a low functioning brain (Alkire et al., 2008, p. 877).

Some anesthetics affect regions of the brain that are responsible for decision making, causing the patient to become unresponsive. For example, small amounts of ketamine, a dissociate anesthetic, cause depersonalization, delusions, and other strange effects. Larger amounts make the face appear blank and unfocused although the eyes are open (Alkire, Hudetz, and Tononi, 2008, p. 876). Past studies have shown that while anesthetics cause amnesia, the patient does not have to be unconscious for loss of memory to occur. It takes less anesthesia to induce amnesia than unconsciousness and immobility (Orser, 2007, p. 58).

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Chapter 8

Telegraph and Telephone

Introduction

Before the telegraph, people used various methods for communication at a distance. The earliest method, which only worked for relatively short ranges, was the use of visual and auditory signals such as flags, fire, and drums. One interesting device was the semaphore, which had a pair of arms, which the operator would place at different angles to form letters. Another popular invention was George Murray’s mechanism, which formed letters by opening and closing a series of six shutters (“Telegraph”, 2009, p. 2). These methods became obsolete with the invention of two well-known devices, the telegraph and the telephone.

The Telegraph

People began using wires and waves to transmit printed messages in the middle of the nineteenth century (“Telegraph”, 2009, p. 1). The first electric telegraph was the product of much research and was not simply a sudden invention. At first, inventors tried to use pitch balls and sparks, but they were unsuccessful. Alessandro Volta invented the voltaic cell, which powers devices utilizing low voltages and high currents and was used in the first telegraph. In addition to Volta, Orsten Sturgeon, Faraday, and Henry made important discoveries in electromagnetism that made the telegraph possible (“Telegraph”, 2009, p. 2).

Early telegraphs came from a variety of inventors. Sirs William Fothergill Cooke and Charles Wheatstone invented the first telegraphs. Their machine comprised six wires and five needles fixed to galvanoscopes that indicate letters and numbers on the receiver. Samuel F. B. Morse, who was an art professor at the University of the City of NY, devised a system of dots and dashes to represent letters and numbers. Later, this system came to be known as Morse Code in his honor. He also developed a newer telegraph machine, which used what is called a portarule in the transmitter. This mechanism had molded type with the dots and dashes of Morse Code, and it worked by closing and opening the circuit formed by the battery and the wire as the type passed through it. The receiver, or register, utilized electricity from the transmitter to control a stylus that imprinted the dots and dashes onto a long strip of paper (“Telegraph”, 2009, p. 2).

With time, the telegraph changed. Morse partnered with Alfred Vail to improve on the former’s original device. They replaced the portarule with a make-and-break key and refined Morse Code so that the most frequently used letters were the easiest letters to transmit. In addition, they improved the basic of the various components of the device (“Telegraph”, 2009, p. 2). The applications of the machine also changed. The first application was in railroad control; the United States government paid to build a sixty mile telegraph line, initiated May 24, 1844, along a railroad from Washington, D.C. to Baltimore, Maryland (“Telegraph”, 2009, p. 4).
The Zimmermann Telegram

It was the Zimmermann telegram that caused the United States to enter World War I. Prior to this message, the United States remained neutral in the war from 1914 to 1917 (Duffy, 2003, para. 1). Because Germany was upset with the British naval blockade, they ceased restricting use of submarine warfare, prompting the United States to break diplomatic ties with them (Duffy, 2003, para. 3). British cryptographers intercepted and deciphered a telegram from the German Foreign Minister, Arthur Zimmermann, to the German Minister to Mexico, von Eckhardt (Duffy, 2003, para. 5).

Zimmermann’s statements in the telegram had major implications for the United States. He claimed that Germany would begin unrestricted submarine warfare and still attempt to keep the United States neutral in the war. If they were to fail at this goal, they would ally with Mexico and compensate this Latin American country with territory from New Mexico, Texas, and Arizona at the end of the war. Zimmermann urged von Eckhardt to share this plan with the Mexican president and to have the Mexican president communicate their involvement in the war with Japan (Zimmermann Telegraph, 1917). The legitimacy of the telegram was verified by a speech in which Zimmermann mentioned it (Duffy, 2003, para. 5), and in February, Great Britain presented the telegram and its contents to President Woodrow Wilson (Duffy, 2003, para. 7). This telegram, known as the Zimmermann telegram, encouraged the United States to enter World War I (Duffy, 2003, para. 6), and on April 6, 1917, the United States Congress declared war on Germany and its allies (Duffy, 2003, para. 8).

The Titanic and Distress Signals

Without the telegraph, ships in distress, such as the Titanic, would be stranded without help. In the year 1912, the Titanic departed for her maiden voyage from Southampton, England to New York, New York (“Titanic”, 2009, para. 1). This ocean liner was supposedly unsinkable because four of the sixteen compartments in the double-bottomed ship could fill with water before the ship could sink (“Titanic”, 2009, para. 2). Late the night of April 14, the boat hit an iceberg approximately 640 km south of Newfoundland. Of the sixteen compartments, five ruptured and filled with water. Because they were all near the bow, the front end of the ship was plunged into the water, and at 2:20 AM on April 15, the ship sunk (“Titanic”, 2009, para. 3).

The ship was in desperate need of help. The Titanic sent out distress signals, using both CQD, which means “All stations, distress” and the newer SOS, which was chosen as a distress because it was easy to transmit and to recognize and does not in fact mean “Save our ship” (McEwen, 1999, para. 7-9). The Californian, the ship closest to the Titanic, did not receive the signals because it did not have a radio operator on duty. However, another ship, the Carpathia, responded to the signal and arrived on the scene an hour and twenty minutes later to rescue survivors (“Titanic”, 2009, para. 4). The incident influenced the international regulations regarding sea voyages, and the following modifications were made to the international regulations for boats: there must be enough lifeboats for all passengers on board, the crew must perform lifeboat drills en route, and all ships must have a constant radio operator (“Titanic”, 2009, para. 7).
The Telephone

The telephone eventually replaced the telegraph. The newer device had an advantage over the older one because it eliminated the need for an operator and because it provided a means for direct voice communication at a distance. In contrast to a telegraph, a telephone works by converting sound waves into similar electromagnetic waves on the transmitting end. These waves are then changed back to the original form on the receiving end (“Telephone,” Encyclopedia Americana, 2009, p. 1).

Alexander Graham Bell invented the original telephone and patented it in 1876 (“Telephone,” Encyclopedia Americana, 2009, p. 1). Bell almost did not receive the patent for the phone because a few hours after Bell filed for a patent, another inventor, Gray, filed for a caveat, and at this point, neither had made a successful prototype. Because Bell filed first, he was credited with the invention, and his patent was for the actual device and the system (“Telephone,” Encyclopedia Britannica, 2009, page 12).

Similar to the telegraph, the telephone evolved since it was invented. With time, the size and the complexity of the device increased (“Telephone,” Encyclopedia Americana, 2009, p. 1). The device originally used wires that were not efficient at transmitting signals across great lengths, so larger wires replaced them. Triode vacuum tubes became amplifiers, which were also referred to as repeaters. These improvements helped to strengthen the signal and increase the clarity of messages (“Telephone,” Encyclopedia Americana, 2009, p. 2).

As time progressed, improvements occurred in signal transmission. On Jan 25, 1915, the first transcontinental phone call was made by Alexander Graham Bell in New York to Thomas A. Watson in San Francisco. Soon after this, the radiotelephone, which was commercially introduced in 1927, allowed for transatlantic phone calls. However, it was unstable, and the lines were often busy. Submarine lines were later placed for transoceanic calls. These lines were more reliable, but they remained inadequate. Introduced in August, 1960, satellite transmission produced a higher quality at a lower cost (“Telephone,” Encyclopedia Americana, 2009, p. 2). The newer digital transmission was a code of pulses from binary pulses, and it eliminates the distortion and weakening of the sound (“Telephone,” Encyclopedia Americana, 2009, p. 4).

Modern phones are electronic-based. Instead of carbon transmitters, they have small electronic microphones, and keypads replaced the dials. Electronic ringers and ringtones now signify incoming calls, and new features, such as redial and speed-dial are standard on most phones (“Telephone,” Encyclopedia Britannica, 2009, p. 14). Mobile phones are portable, and they can work almost anywhere. Mobile phones, especially ones like the iPhone, have many features other than to simply make calls (“Telephone,” Encyclopedia Britannica, 2009, p. 16). The invention of the telephone led to other new technologies, such as the Internet, which is now a vital part in the lives of most people. Recently, telephone, Internet, and even television have switched to fiber optics to increase bandwidth and reliability and to lower cost (“Telephone,” Encyclopedia Britannica, 2009, p. 3).
The Watergate Scandal

The telephone contributed to Nixon’s impeachment in the Watergate scandal. In late June 1972, five men were arrested at the Watergate Hotel for breaking into the headquarters of the Democratic National Committee. These five men, along with E. Howard Hunt, Jr. (a former White House aide) and G. Gordon Liddy (general counsel for the Committee for the Re-election of the President) were charged with burglary and wiretapping (“Watergate Scandal”, 2009, para. 2). Many reports that incriminated people of Nixon’s administration were released in the Washington Post, and the source of most of the evidence was a man referred to as Deep Throat (In reality W. Mark Felt) (“Watergate Scandal”, 2009, para. 3). The incident defamed the image of Nixon and his administration because they listened to the private conversations of their political opponents. A formal impeachment inquiry was begun in May 1974 (“Watergate Scandal”, 2009, para. 12). In July of that year, three articles of impeachment were passed, and on August 8 Nixon announced his resignation. He left office the next day at 11:25AM (“Watergate Scandal”, 2009, para. 13).

The Future of the Telephone

The telephone is far from complete. With new technology constantly being developed, the telephone keeps advancing, especially mobile phones. These devices currently have very complex features, such as cameras, music players, and games, something Bell would never have dreamt for his invention. These small portable phones can also connect to the Internet, which was originally based on phone lines, and some can function as tiny computers. From here, the phone can continue to evolve as the technology for computers and the Internet evolves as well.

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Chapter 9

Antibiotics

History of Antibiotics

Since the beginning of recorded human history, people have used compounds with the belief that they would ward off infectious diseases (Rollins, 2000, para. 1). More often than not, these drugs did nothing, and patients were left untreated. The only possible benefit of most of these compounds was perhaps some sort of placebo effect. The lack of any proper way to cure infectious diseases left the world in a very dire situation. During World War I, more than eighteen percent of bacterial pneumonia infections proved fatal among soldiers (Wong, n.d., para. 30). It is interesting to note that such a common infection was considered so virulent before the advent of antibiotics. In fact, a host of infections now considered mundane, such as strep throat, were normally fatal when contracted. It is a true testament to the progress of medical science that doctors had absolutely no way to fight these bacterial infections just eighty years ago. A series of important discoveries, caused both by flashes of brilliance and by luck, has shaped the modern battle against microorganisms.

History

The story of antibiotics starts with Louis Pasteur in the nineteenth century. Working in France, Pasteur was a proponent of the so-called germ theory of disease (Wong, n.d., para 10). However, Pasteur was not in actuality the first to observe bacteria in a laboratory. That honor goes to Anton Van Leeuwenhoek in the 1670s (Abedon, 1998, para. 5). Rather, Pasteur’s claim to fame is that he was the first to prove the existence of bacteria to his contemporaries beyond a reasonable doubt using rigorous experimentation. He was the founder of the process of pasteurization, whereby microorganisms present in food are killed through boiling. While Pasteur’s discoveries were major milestones in medical science, they were still useless when it came to treating bacterial diseases. Joseph Lister is usually credited with introducing germ-killing agents into hospital settings (Wong, n.d., para. 13). Lister began using carbolic acid to prevent post-operative infections, mainly septicemia, in his patients (Hume, n.d., para. 9). By the time he died in 1912, antiseptics were being used widely by surgeons to prevent bacterial infections.

One scientist who did not believe that antiseptics were a true solution to the problem of bacterial diseases was Alexander Fleming. Fleming agreed that antiseptics were able to kill bacteria, but he objected to their use in patients because they killed human cells with the same frequency as bacterial ones (Wong, n.d., para 13). Fleming was doing an experiment with a strain of *Staphylococcus aureus* when he happened to notice that some of his samples were contaminated with a common mold. Upon closer inspection, he realized that the mold was actually inhibiting the growth of the bacteria, and he identified the mold as *Penicillium notatum* (Wong, n.d. para 10). Interestingly, Fleming was by no means the first to make this discovery. John Tyndall, Ernest Duchesne, Andre Gratia, and Sara Dath all noted the antibiotic properties of the *Penicillium* genus of molds before him (A Brief History of Penicillin, 2006, para. 2).
Fleming was special because he was the first to try to find medicinal applications for his discovery. Sadly, Fleming was unable to produce his compound, which he named penicillin, in large enough quantities for actual use. The first person to use penicillin to treat an infection was one of Fleming’s former students, Cecil Paine. Paine used penicillin extract, with resounding success, to treat a baby who had contracted gonorrhea of the eye (Wong, n.d., para. 14). The penicillin supply was very low until a new Penicillium mold, *P. chrysogenum*, was discovered growing on a cantaloupe (para. 17). Prior to the discovery of this new mold, which produced approximately two hundred times as much penicillin as *P. notatum*, it was said that "you could get more gold out of ordinary seawater than penicillin out of the mold" (para. 14). Once penicillin production began to meet its demand, the drug became an overwhelming success. Only one percent of World War II soldiers who contracted bacterial pneumonia died as a result of the disease (para. 30), a drop of seventeen percent in just a thirty-year span.

**Method of Penicillin Action**

Penicillin affects mostly gram-positive bacteria, meaning ones which contain cell walls with large amounts of peptidoglycan. However, penicillin is also useful against certain species of gram-negative bacteria, namely gonococci, which cause gonorrhea, and meningococci, which cause meningitis (Schegel, 1986, p. 48). In general, penicillin works by changing the cell wall structure of bacteria. When exposed to it, bacterial cells become what are known as L-Forms, or irregularly large cells (p. 48).

These giant L-forms are unable to synthesize cell walls and they quickly perish without the walls. Although penicillin is somewhat effective in bacteria, many are able to produce the enzyme penicillinase, which can inhibit the action of penicillin. In order to combat penicillinase, new synthetic penicillins, which vary structurally but are identical functionally, are often produced to combat penicillin resistance in bacteria (p. 343).

**Modern Antibiotics**

From the moment that it entered the market, penicillin had widespread ramifications for twentieth century society. The discovery of penicillin had a very tangible, if somewhat improbable, effect on the history of baseball. One of the most recognizable players of the twentieth century, Mickey Mantle, had osteomyelitis, a potentially fatal infection of the bone. He was presented with two options, leg amputation or a course of penicillin. He chose the latter, and his condition improved drastically. He went on to become a Hall of Fame player and one of the most important figures in New York Yankees history (Wong, n.d., para. 6). The introduction of antibiotics had very similar effects across all segments of society. Such stories were common, and infections which would otherwise have either killed or crippled their hosts were now becoming easy to treat.

Unfortunately, the initial optimism about penicillin was somewhat dampened by the advent of antibiotic resistant bacteria. Soon after the discovery of penicillin, a number of other compounds with antimicrobial properties were discovered. The first such drug was sulfonamidochrysoidine, discovered by Gerhard Domagk in 1935. Not technically an antibiotic, this drug was different from penicillin in that it was not derived from an organic source. Rather, it
was synthetically produced in a laboratory. This drug prevented bacteria from reproducing by inhibiting production of para-aminobenzoic acid (Rollins & Joseph, 2006, para. 1). However, as these sorts of drugs were being developed, bacteria were simultaneously gaining immunity to many of them.

As the search for antibiotics became an increasingly lucrative and rewarding business, researchers discovered other common drugs such as cephalosporin, streptomycin, chloromycetin, and gramicidin (Schegel, 1986, p. 48). Each of these targets a slightly different set of bacteria and has a different method for killing them. The body of antibiotics which had been synthesized or discovered by the early 1950s included such powerful drugs as streptomycin, chloramphenicol and tetracycline. As a whole, these drugs were able to treat every imaginable bacterial infection (Todar, 2008, para. 10). In 1958, one of the most effective antibiotics to date, vancomycin, was discovered by Dr. E.C. Kornfeld in a soil organism from Borneo known as *Streptomyces orientalis*. It was immediately found to be highly effective against staphylococcal strains (Moellering, 2006, para. 2). Because it has remained so effective against staphylococci and other gram-positive bacteria, it is one of the few antibiotics which is restricted to use in hospitals.

**Drug-Resistant Bacteria**

Sadly, vancomycin is one of the few long-term success stories in the world of antibiotics. Even though it is such a powerful antibiotic, a vancomycin-resistant strain of *Staphylococcus aureus* was found in 2002 (Moellering, 2006, para. 4). This discovery was a major loss in the battle between modern medicine and bacteria, considering that vancomycin had gone almost half a century without the development of any significant strains of resistant bacteria. The development of drug resistance is by no means a phenomenon unique to vancomycin. In fact, bacteria have developed resistance to almost every major antibiotic drug. One of the first major outbreaks of a multiple-drug resistance bacteria occurred in Japan in 1953, less than a decade after the general introduction of antibiotics. In this outbreak, researchers found a strain of *Shigella dysenteriae* to be resistant to all antibiotics which had been discovered up to that point (Todar, 2008, para. 11). The discovery that this *Shigella* strain was able to develop resistance so rapidly was only a harbinger of events yet to come.

There are now many bacteria which are resistant to a wide range of antibiotics. Among the most important and lethal are MRSA (methicillin/oxacillin-resistant *Staphylococcus aureus*) and VRSA (vancomycin-resistant *Staphylococcus aureus*) because they are resistant to the antibiotics most commonly employed in hospital settings. Therefore, they are able to thrive in healthcare establishments. These bacteria cannot be treated easily with any common antibiotics and are potentially very deadly. In fact, MRSA alone contributed to 18,650 deaths in 2005 (para. 21).

Bacteria like *Staphylococcus aureus* are able to develop resistance to drugs because of their ability to mutate. Such bacteria are able to mutate through both vertical and horizontal gene transfer. In vertical gene transfer, an organism which has already developed resistance can reproduce asexually, thereby directly passing on resistance to its offspring. The more interesting type of gene transfer is horizontal transfer. In this process, bacteria can share genetic material with one another, either through direct contact or through viruses which transport genetic
material (Wong, n.d., para. 38). Researchers believe that approximately one in every $10^9$ bacteria develops resistance to an antibiotic (Wong, n.d., para. 36). Because these bacteria are so effective at transferring their genetic material to one another, a single mutation can result in scores of resistant bacterial cells.

**The Impact of Antibiotics**

Although there are many strains of antibiotic bacteria now present in hospital wards, antibiotics have effectively served their original purpose over the course of the past eighty years. They have been able to treat the infections of countless individuals and saved millions of lives. Antibiotics have changed the way in which many common diseases are viewed. Being infected with bacterial pneumonia, for instance, is no longer considered fatal. Rather, it is viewed as a mundane infection which can be cured with a simple course of antibiotics. The number of antibiotics available for use has also affected their impact on society. Even if one antibiotic is ineffective at treating a disease, there are, for most common infections, a host of other drugs that can be used to effectively cure the disease. The development of antibiotics over the past eighty years has changed the relationship between humans and disease. Antibiotics have given humans the power to fight back effectively against microorganisms in a way that would have been considered impossible just a century ago.

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Chapter 10
Engines

Part I: The Steam Engine
The Impact of the Steam Engine on History

Sources of energy are vital to the development of civilizations. Without energy, society cannot function and perform even the basic actions necessary for life. With energy to spare, however, society becomes more efficient, develops new ideas and innovations, and advances. Until the late 1600s, sources of energy were confined to human strength, draft animals, wind, and water. The breakthrough of a practical steam engine in Europe at this time of change drove global industrialization, eased transportation, and increased the overall productivity of the world.

Modest Beginnings

In order for the world to benefit from new discoveries, people need to understand how to use innovations to their advantage. Manuscripts about steam power are as old as the 1st century, but this technology was not applied until much later. Hero of Alexandria described a method of opening temple doors and spinning a globe using fire and water. Hero’s apparatus consisted of a fire-heated cauldron filled with boiling water at the altar of the temple that produced steam. The steam traveled through pipes to the temple doors and the force of the steam could open the doors. Hero also described a similar cauldron that was placed underneath a globe. As steam escaped from two pipes, the air pressure above became uneven causing the globe to spin (Bolon, 2001, para. 3). Although Hero realized a powerful energy source with numerous possibilities, his investigations with steam power were not acknowledged because people had no interest or need for them. Following Hero, several other inventors and scientists experimented with steam power before it became accepted, including Blasco de Garay, Giovanni Battista, Leonardi da Vinci, and Edward Ford (Bolon, 2001, para. 6-8).

The First Practical Steam Engine

Despite past experimentation with steam power, Thomas Savery of Devonshire England was the first person to make steam power useful. He produced a functional, practical steam engine in 1698. Savery came from a wealthy, well-educated family and became an innovative engineer with breakthroughs in clockwork and paddlewheels for ships. Savery’s most prominent invention, however, was his development of a steam engine. British mines often filled with water and Savery’s water pumping engine model worked to solve this problem. He called his invention the “fire engine,” because the production of steam was compelled by fire. The fire engine had multiple purposes: it could drain mines thus supplying towns with water and it could potentially provide power for mills that did not have access to consistent winds or water (Thurston, 1878, ch. 1).

This engine comprised a furnace, boiler, pipes, and copper receivers. The furnace heated the boiler producing steam which moved upward into multiple pipes and then downward into a
single pipe. The change in atmospheric pressure formed a vacuum in the pipe that sucked water from a reservoir up towards the surface.

Thomas Savery’s steam engine. Steam pressure is used directly to produce a vacuum which will drain water. (Thurston, 1878, “A History and growth of the steam engine,” ch. 1)

The first design raised water up to 24 feet in the air, but this height was improved with later models. Miners would often cease progress if large amounts of water were found because removing the water by human and horsepower was too expensive. Savery’s engine, however, known as “The Miner’s Friend”, overcame that obstacle at a cheaper rate (Thurston, 1878, ch. 1). The development of Thomas Savery’s engine marked the first time humanity used steam power towards a practical purpose.

Changing Motion

Although Savery’s engine was an innovative breakthrough that utilized a new source of energy, it was far from efficient and had many safety and function problems. The second major advancement of the steam engine was introduced by Thomas Newcomen in 1712. His engine also used steam from boiling water, but it had a piston which produced an up and down motion. The changes in heat energy and the changes in air pressure were converted to work which returns movement.

Newcomen’s engine was very large and was typically contained in an engine house about three stories high next to a mine shaft. A wooden beam which moved up and down extended from top of the house. At the bottom of the shaft was a water pump, which was connected to the engine by a pump-rod. There was a brass cylinder inside the house atop a brick boiler which was fed coal and supplied heat and steam. A piston inside the cylinder was connected to the beam above. Once the cylinder was filled with steam from the boiler, it was sprayed with cool water causing the steam to condense and create a vacuum. This vacuum pressured the piston to move
downwards thus rocking the beam and pulling up the pump rods, sucking water. Each motion of the beam sucked approximately twelve gallons of water.

Newcomen’s engine. Steam pressure forces the large lever at the top to move up and down, pumping water (Bolon, 2001, “The Steam engine”).

Newcomen’s engine, also known as the beam engine or atmospheric engine, converted the steam pressures into a new form of mechanical energy that was much more effective than Savery’s engine, which produced no motion (Steam engine – history, para. 4).

The Biggest Improvement

Approximately fifty years after Thomas Newcomen, a young mechanical engineer and inventor named James Watt began tinkering with the steam engine in 1763 at Glasgow University. He moved on to other research, but 25 years later he studied engine again. The English government recognized the innovation and potential of the steam engine, so they requested Watt to improve Newcomen’s engine by making it more efficient and powerful (Bellis, n.d., Newcomen steam engine section, para. 2). Watt realized that energy was wasted by reheating the cylinder again and again after cooling it to condense the steam, so Watt added a separate condenser to the engine. This allowed the machine to work constantly because there were no pauses in the process to reheat the cylinder. James Watt also adjusted the engine so that steam could enter on either side of the piston, so that the up and down motion of the piston was more forceful. The beam was connected to a gear, producing circular motion. Watt also added a pressure gauge so that the amount of power produced from the engine could be measured (Steam engine – history, para. 5).
Watt’s new engine was the greatest improvement in retrieving energy from steam power. It was almost 75% more efficient than any of the previous models, produced circular motion, and was self-regulating. The efficiency of Watt’s engine was clearly significant because it produced much more energy than the previous steam engines and used less fuel. The circular motion produced from Watt’s engine could be used to power transportation, like the steam engine and steam boat. Finally, the separate heating and cooling system allowed the engine to work constantly without an overseer (Bolon, 2001, para. 12). The enhancements equipped to the steam engine by James Watt made the steam engine a dominating power source.

The Steam Engine Changes the World

The most significant impacts of the steam engine occurred during the Industrial Revolution which began in the eighteenth century. James Watt improved the steam engine during a time when a new energy source could be useful and appreciated. The Industrial Revolution was the process of change from an agrarian civilization based on farming and handicraft to an industrial civilization based on manufacturing and machines. James Watt’s developments on the steam engine were part of a burst of inventions and discoveries. While, none of the steam engine technologies prior to Watt were generally accepted, Watt’s steam engine gained high reclaim during the Industrial Revolution. Watt’s innovation provided a source of energy and power, encouraging the momentum of the world change.

The steam engine directly inspired the Industrial Revolution because it was the source of the power which drove the technologies. Coal was recently discovered as a new, resourceful fuel to replace wood, wind, and water. Coal had to be mined, however, and there were often problems with flooded mines that hindered the extraction of coal. The steam engine solved this problem by pumping out the water. Coal was the chief fuel for numerous factories and machinery during the nineteenth century, and the steam engine was necessary for the collection of this fuel. The steam engine advanced the industrial strength of mining in general, improving the iron business as well
as coal (Steam engine history: development and effects, 2009, para. 3). As Britain was the first to develop the use of the steam engine in mines, the steam engine was especially important to the rapid growth and advancement of Britain in comparison with the rest of the world.

Developments of the steam engine during the Industrial Revolution allowed the engine to produce constant movement which powered faster, independent forms of transportation. The circular motion developed by James Watt was critical to the discovery of the steam locomotive and steam boat. Further advancements by Richard Trevithick, Oliver Evans, and Robert Fulton made the steam engine strong enough to power these large vehicles of transportation. In contrast, transportation was slow and difficult prior to the steam engine and relied solely on energy from draft animals or the wind. Railway systems on land and steam boats in the water aided the movement of goods and people. As a result of improved transportation, local and international trade increased. The production and distribution of goods also helped to satisfy the high demands of the people in this time period, stabilizing the economy. Faster transportation additionally encouraged larger movements of people, inspiring a rise in immigration and causing rapid cultural dispersion. With the effects of the steam engine on transportation and industrialization, the steam engine had a significant impact on several social and economic characteristics of the nineteenth century.

The Future of the Steam Engine

While the steam engine was most influential during the time of the Industrial Revolution, the engine is still used today for several of its original purposes. Since James Watt’s improvements, inventors have redesigned the steam engine to maintain higher steam pressure, thus making the movements stronger and more forceful. Steam power may be considered to be old fashioned, but it is still one of the most powerful sources of independent energy. Inventors and engineers are constantly attempting to make improvements on the engine, in hopes to reapply its practical purposes. Recently, scientists and inventors have developed the steam engine so that it is solar powered, making this strong source of power more energy efficient. The steam engine has not yet been made safe and affordable enough to be used as a home generator, but this application of the steam engine is a new possibility for the future (Goebel, 1998, para. 2). Although new technologies have replaced steam power as popular methods of transportation, the steam engine is still a strong, functional energy source that people continue to improve.

The steam engine had a significant impact on history by influencing social and economic changes in the world. While steam power was not immediately popular upon its discovery, the immense potential of steam power enabled a change in the main source of energy and most prominently powered the shift to industrialization. Without the steam engine, the world may not have changed into the fast-paced, industrial world it is today.
Katherine Karwoski

Part II: Internal Combustion Engines

Introduction

An engine is a device that receives some form of energy and converts it into mechanical energy (“Engine,” 2009, para. 1.). Engines have been transforming humanity since their inception, and the internal-combustion engine, being the most common type of engine, is no
exception. There are two main types of engines—internal-combustion engines and external-combustion engines. Steam engines and Sterling engines are examples of external-combustion engines; gasoline engines and jet engines are types of internal-combustion engines (‘‘Engine,’’ 2009, para. 1.). An internal-combustion engine is an engine in which gases from burned fuel drive a mechanical cycle. The first such engine was constructed in 1794 by Robert Street, and since then, internal-combustion engines have had significant impact. Internal-combustion engines have enabled humans to increase the amount of work being done and have enabled travel farther and faster by powering boats, cars, and planes. Despite the positive impact these engines have had, there has been negative impact as well. Increasing use of internal-combustion engines to drive transportation has led to an increase in the demand for fossil fuels, as well as increasing environmental pollution (Starkman, 2009, History Section, para. 1). Having become such an integral part human life, internal-combustion engines have had enormous impact on society.

History

The first viable internal-combustion engine was produced in 1794. Early internal-combustion engines were clumsy, slow, and attention-intensive. Throughout the early 18th century, advances continued to be made, with engineers experimenting with vacuum piston engines and free piston engines. But the next notable advance came in 1866 when Nikolaus Otto and Eugen Langer produced a much more efficient engine with a flywheel for the piston. Beau de Rochas, attempting to increase efficiency further, came up with the 4 essential stages of an engine cycle. Otto applied the theory and produced the first 4-stroke engine in 1876. Since then, minor changes have been made to decrease weight and size and to increase efficiency and speed. The reciprocating, spark-ignited gasoline engines used in cars today are largely similar to the original ones. Other types of engines were also built. 1873, George Brayton produced a 2-piston engine that kept constant pressure throughout the cycle, forming the foundation for future gas turbines. Rudolf Diesel applied Rochas’ principles differently and built the first compression-ignition engine in 1895, known today as the diesel engine, after its inventor (Starkman, 2009, First practical engines section and 19th century developments section; Duffy, 2009a, para. 2).

The Science of Combustion

The fundamental principle that the internal-combustion engine relies on is the ability of certain materials, namely fossil fuels (usually liquid), to combust. The key ingredient in these fuels is octane. The octane, when ignited, undergoes a chemical reaction, transforming into gases, namely hydrogen and carbon dioxide, and other byproducts. Under the heat of the engine and chemical reaction, these gases expand, driving the piston of the engine downward. The pistons are connected via a rod to a crankshaft, which connects to other mechanisms that drive the other parts of the machine. For example, in a car, the crankshaft would connect via rods and shafts to the axles that drive the wheels.

Gasoline versus Diesel

The two main types of internal-combustion engines used are the spark-ignition engine, commonly known as the gasoline engine, and the compression-ignition engine, commonly known as the diesel engine. The major difference between the two types, as the formal names
imply, is how the air-fuel mixture is ignited. The spark-ignition engine includes a spark plug, usually at the top of the combustion chamber that sparks at the proper interval to ignite the flammable gases. The combustion-ignition engine lacks a spark plug, instead igniting the gases through the sheer amount of pressure placed on the air-fuel mixture (Starkman, 2009a, gasoline engines section and diesel engines section.).

Two-stroke and Four-stroke cycles

There are many variations in engines. Perhaps most important is the difference between 2-stroke cycles and 4-stroke cycles is that a 2-stroke cycle has a power stroke for every revolution, whereas the 4-stroke cycle has one power stroke every other revolution. Very small and very large engines are usually 2-stroke; cars are generally 4-stroke (G. Karwoski, personal communication; “Four-stroke cycle,” 2007; “The 2 stroke cycle,” n.d.). In the first stroke of the 2-stroke cycle, induction and compression, the exhaust port is closed, the air/fuel mixture is input into the system, and the mixture is compressed. In the second stroke, ignition and exhaust, the inlet port is closed and the exhaust port opens to release the burnt gases (“The 2 stroke cycle,” n.d.). The power-density ratio is greater in a 2-stroke engine, meaning that more horsepower is constructed for the weight of the engine (G. Karwoski, personal communication).

The strokes of the 4-stroke cycle are called intake, compression, power, and exhaust. In the intake stroke, the exhaust valve is closed, the piston is in the bottom of the combustion chamber, and the air-fuel mixture flows through the open intake valve. In the compression stroke, both of the valves are closed, and movement of the crankshaft causes the piston to move to the top of the combustion chamber, compressing the air-fuel mixture. In the power stroke, the spark plug fires, igniting the gases, causing them to explode and push the piston down forcefully. In the last stroke, the exhaust stroke, the exhaust valve opens and the piston forces the exhaust gases out of the combustion chamber (“Four-stroke cycle,” 2007).

The Four-stroke cycle. This diagram depicts the parts of the four-stroke cycle in engines. (“Four-stroke cycle,” 2007).
The two-stroke cycle. This diagram depicts the parts of the two-stroke cycle. (“The 2-stroke cycle,” n.d.)

Other Variations

There are numerous other variations among internal-combustion engines, based on the function of the engine. The arrangement of the pistons is one major variation. In many industrial settings and in airplanes, the pistons are arranged in a circular fashion. In cars and other smaller applications, the pistons are arranged in two rows at an angle to each other, namely in a V shape. Another variation is the number of pistons. Larger engines have upwards of 20 or 30 pistons, whereas smaller engines can have as little as four. From the former variations comes the typical nomenclature of a car or recreational boat engine. A V-6 engine, for example, would have 2 rows of 3 pistons each, set at an angle to each other. The more pistons there are, the more horsepower the engine has, meaning faster acceleration. Other variations in the subsystems of engines can also affect the performance of an engine (Starkman, 2009a, number and arrangement of cylinders section, para. 1).

Engine Subsystems

There are three subsystems that contribute to the process of ignition in an engine. There is the ignition system, which comprises the spark plug and the distributor. The spark plug provides the spark that ignites the gases and the distributor times the spark correctly. The fuel system consists of either a carburetor or a fuel-injector for mixing the fuel and the air (a ratio one to fifteen). Carburetors atomize the fuel into the air whereas fuel injectors mist the fuel into the air. The starting system consists of a starter motor that has high torque to turn a crankshaft until the engine starts (Duffy, 2009a, Ignition system section, Fuel system section, and Starting system section). Together, these systems start the process.
Historical Impact

The major positive historical impact of engines is their effect on manufacturing and transportation. Engines are used for many manufacturing processes, meaning that the introduction of engines made manufacturing cheaper and faster. This meant that more of the common people could own goods. These goods could also get places quicker, as engines revolutionized transportation. Internal-combustion engines are used on cars, boats, trains, and planes. Such widespread use in transportation meant that people could visit relatives more frequently, they could have lives farther from their birthplace, and they could work farther from home. In short, engines greatly contributed to the urbanization and globalization of the modern day.

Despite their importance, engines also have had negative impact, namely on the environment. In the 1960s, cars produced approximately 60% of pollutants. These pollutants that are a by-product of the combustion cycle have contributed greatly to the impact of humanity on nature. Internal-combustion engines burn fossil fuels, and the global climate change that has been happening is largely due to fossil fuels. At the core of this climate change is the greenhouse effect, keeping the Earth warm. While it sustains life on Earth, this process may also be our demise. The basic principle of the greenhouse effect is that certain gases in the atmosphere, called greenhouse gases, capture the heat of solar energy. The area of the atmosphere facing the sun receives 1,370 Watts per square meter in direct sunlight (IPCC, 2007b, p. 2). This heat is trapped and bounced back down to Earth, keeping the planet warm and us alive. However, emissions of carbon dioxide and other greenhouse gases are rising because of increased usage of and dependence on fossil fuels. These gases, including carbon dioxide, methane, and water vapor, accumulate in the atmosphere and increase the greenhouse effect, making the Earth warmer (“The basics of global warming”, n.d., The greenhouse effect section, para. 1).

The negative effects of the rising temperatures are numerous. As far as weather is concerned, global climate change will cause more droughts, fire, heat waves, and hurricanes. Category four and five hurricanes, the most intense levels, have approximately doubled in number over the past three decades. The Arctic Ocean, which keeps much of the water on the planet locked up in ice, may be ice-free by summer of 2050. This would have catastrophic effects on coastal areas, as the melting of the ice at the poles will cause sea level to rise by more than twenty feet, flooding places such as New York and Boston. Also, plants and animals respond to the heat by moving their range closer to the poles, which at least 279 species have done already. By 2050, global climate change could cause over a million species to become extinct. Humans will be affected more directly as well. Warmer climate is causing mosquitoes to expand in range, spreading malaria to higher places and more people in areas like the Colombian Andes. Also, it is predicted that in the next 25 years, human deaths caused by global warming will increase to 300,000 people a year-- double the current rate (“What is global warming”, n.d., list). These are only some of the fears caused by global climate change, which is caused largely emissions from the burning of fossil fuels in engines.

In conclusion, engines, especially the internal-combustion engine, had a profound impact on society. From their inception in the late 1700s to their industrialization and modernization, engines have affected the way we make goods, travel around the world, and life our lives. Without engine, it is doubtful that society would have advanced as far as it has today.
Part III: The Gas Turbine (Jet) Engine

History

As children, Orville and Wilbur Wright, two bike mechanics, received a small flying machine from their father and found its bizarre properties entrancing, inspiring them to reconstructing the model multiple times during their childhood. It was not until Orville and Wilbur were in their early thirties that they managed to build the first full-scale version of their favorite childhood toy, an invention now known as the biplane. Within fifteen years of the first flight, most countries had modified the biplane, transforming it into a powerful new military asset. However, unknown to any scientists at the time, aeronautical engineers were already beginning to design engine props with tangential speeds near the sound barrier (Johnson, n.d., para. 20). The problems caused by the higher speeds would start a new rift in the aeronautics industry and jumpstart aeronautical research during the cold war.

Despite the growing tensions, it would be decades before engine technology and aeronautical research would advance far enough to stress the divisions between engineers. After two decades of advancements, the piston-engines used to power post World War I planes were nearing at what many aviators thought was their maximum potential (Heppenheimer, 1992, para. 3). Instead of new engines and sleek designs, it was widely believed planes in the future would simply carry as many engines as possible, making them far too bulky for efficient supersonic flight. However, a new technology known as the turbocharger would disrupt this belief (Heppenheimer, 1992, para. 3).

The turbo charger was a simple addition to piston engines that greatly increased efficiency. Invented in France, the turbocharger used hot exhaust gases from the engine to turn a pinwheel, forcing more air into the engines through a parallel intake valve. This advancement allowed for aircraft to operate at higher altitudes, so high that an unprotected pilot would pass out before his aircraft would stall or show any sign of engine difficulties. Even at lower altitudes, the turbocharger provided a welcome boost to engine performance (Heppenheimer, 1992, para. 1-2).

The other invention that contributed to the first jet engine was a device known as the English gas turbine, a generator intended as an immobile source of mechanical power. Unlike the turbocharger, the English gas turbine was much less popular among its customers because it would commonly waste large amounts of fuel, making it economically for useless. The potential for gas turbines to revolutionize flight were seen as early as 1908 when the first patent was awarded for a so called jet engine, but most attempts to actually construct engines failed. (Heppenheimer, 1992, para. 4). Strangely, the jet engine would be invented by two different teams of scientists, one in Germany, and one in Great Britain.

When the World War II began, the Axis and Allies began pressuring their scientists to find new technologies capable of giving them an advantage over their enemies, and the gas turbine engine was just starting to show its potential. The Axis began funding a program to develop jet engines before the Allies, thanks to Hans Vahn Ohain and his car mechanic, Max Hahn. Together the college graduate and mechanical expert managed to develop a prototype of a primitive turbojet engine, but it was generally regarded as a failure because the engine could not run without the help of a conventional piston engine for support. The so-called failure was
enough to make Ohain and Hahn visible to the aviation industry and led to their employment by a major German airplane contractor. There Hahn and Ohain refined their prototype until 1939, when they finally ran a self contained, gas powered, engine capable of producing over a thousand pounds of thrust, enough to warrant the construction of the first jet aircraft, the HE 178 (Heppenheimer, 1992, para. 6-10).

While the Axis had Max Hang and Vahn Ohain, the Allies had Frank Whittle, a lone Royal Air force (RAF) Officer who built his engines in an abandoned factory. Whittle became interested in jet theory when he graduated fifth in his RAF training class and was subsequently accepted into officer training. To become an officer Whittle had to write a substantial paper, and he chose future aircraft design as his topic. In his paper Whittle predicted that planes would eventually travel under rocket power, but after turning it in, he realized gas turbines would provide a more reliable alternative to rocket propulsion. By 1930 Whittle had refined his ideas enough for a successful patent application, but he lacked the engineering knowledge necessary to actually construct his patent. Luckily for Whittle the RAF required all officers with four years of military service to choose an area of specialization and take courses on that specialty; naturally Whittle chose engineering (Heppenheimer, 1992, para. 13-17).

The supervisors of the officer training program quickly recognized Whittle for his advanced abilities and sent him to Cambridge University. In 1935, while still studying at Cambridge, an old classmate contacted Whittle and offered to help him secure funding from businesses in order to make his turbine ideas a reality. Inspired by the gesture, Whittle went on to graduate with honors in 1936, after which the RAF granted him an extra postgraduate year to allow him to work on his engines. In early 1937 Whittle finished his first prototype, the Whittle Unite, but it produced very little thrust and was basically made from junkyard scrap. However, just having a running engine was enough to convince the RAF to allow him to continue with his project. Unfortunately his success was not all good news; the commotion Whittle caused during his tests disrupted construction at the factory he used for workspace, leading to his eviction. Undaunted, Whittle moved his lab to a run down factory seven mile away where he was commonly confronted by local police for building bombs that Irish rebels used (Heppenheimer, 1992, para. 17-23).

Whittle finished his first real engine one year before his German competition, but a compressor malfunction caused the engine fan blades to fracture, detach, and rip apart the engine. It would be another year until Whittle had repaired his engine. Despite earlier completion, the British engine was much less powerful than its German counterpart, producing just four hundred and eighty pounds of thrust. Despite its shortcomings, the engine surprised the RAF and they permanently assigned Whittle to his engines, ordering a new design capable of powering an experimental jet that would be called the Gloster Comet(Heppenheimer, 1992, para. 23-27).

American officials eventually learned of British advances in gas turbine technology nearing the American entry into the war in late 1941. Representatives sent to Great Britain to watch over shipments of B-17 bombers began overhearing rumors of the Whittle engines, leading to coordination between Britain and America on the subject. Within half a year, prototypes of the British engines as well as their blueprints had made arrived in America, and before the next year Bell Aviation constructed the X-59A, the first American jet aircraft. It flew at a maximum speed of just 410 mph, no better than a high quality piston powered aircraft from
that same time, leaving the German scientists well ahead of those of the Allies (Heppenheimer, 1992, para. 28-36).

Unfortunately for the Axis, Allied bombing raids continued to take heavy tolls on the German economy following the American entrance to the war. Factory and infrastructure destruction led to a slow down in the development of a miracle weapon Hitler saw as the last chance to push back allied advances. The miracle was the Me262, the first jet fighter to see combat. In the four years between the economic downturn in Germany and the first successful jet engine test, Hahn and Ohain had been surpassed as the premiere German jet designers by their competition, Anselm Franz, who managed to design the Jumo 004, an engine capable of producing one thousand three hundred pounds of force. The extra thrust produced by the Jumo was largely due to its axial compressor, the first incorporated into a gas turbine design. The German government approached the Messerschmitt Company in 1938, before the Jumo 004 was even completed, and asked them to design what would become the Me 262. The first prototype flew for the first time in 1942 and astounded onlookers as it left the airfield at a nearly vertical angle, climbing with unprecedented speed (Heppenheimer, 1992, para. 29-33).

Before the skies of Germany could be recaptured by the Me262, Allied blockades of German imports led to a shortage of heat resistant materials that made mass producing the Jumo 004 engines that powered the Messerschmitt 262 economically impossible. For two years scientists experimented with ways of reducing the amount of metal used in the engine, and the result was a 1,650 pound motor capable of producing two thousand pounds of force, an increase of seven hundred pounds of thrust while only using five pounds of chromium and six pounds of nickel (Heppenheimer, 1992, para. 42-43).

With only a year left in the war and the German economy in ruin, it is astonishing that any Me 262s were produced at all, let alone a thousand of them. However, the late introduction of the Me 262 made the new technology irrelevant to the overall path of the war. Lack of materials, workers, pilots, and machinery ultimately led to the elimination of the Messerschmitt fighter as a threat to the course of the war. On one occasion, two Messerschmitts showed what would have happened if production had gone as planned when they destroyed a squadron of twelve Allied piston aircraft, but such victories relied entirely on the element of surprise. To prevent further embarrassments, Allied fighters began scheduled patrols over German airfields, shooting down any planes before they even left the ground. Without the element of surprise, the Me 262 never had a chance, and the miracle machine Hitler had hoped would save Germany came as just a curiosity to the Allies (Heppenheimer, 1992, para. 44-51).

After Word War II, the surge in innovations that defined the aircraft industry during the war slowed down as engineers struggled to understand a set of difficulties collectively known as compressibility problems, or situations in which speed caused a decrease in the lift generated by an airfoil. Although compressibility problems had been slowly collected since induction of the biplane, the first death they caused was not recorded until just before World War II started. During test flights for the American the American piston powered P-38 Lightning the test pilot, Ralph Virden, took the plane into a dive as part of the routine flight test. However, when Virden tried to pull out of the dive, his controls had no affect on the aircraft, causing it to crash directly into the ground (Anderson, n.d., para. 65-66).
Prior to the crash aviation engineers had generally assumed that the pressure differences caused by airflow over a wing was negligible despite research conducted by Frank Caldwell and Elisha Fales in 1918 that said otherwise. The two scientists used the first high-speed wind tunnel to test the affect of high speed airflows on the ability of various airfoils to produce lift, and what they found was that as speed increased the amount of lift generated by each airfoil decreased drastically while the friction caused by the airflow over the wing increased dramatically. These affects did not occur over time, but rapidly after a specific speed, known as the critical velocity, was passed. Form the tests Frank Caldwell and Elisha noted that the thinner an airfoil was, the higher the critical velocity was (Anderson, n.d., para. 21-24).

In the early 1930s another scientific team, Lyman J. Briggs and Dr. Hugh L. Dryden, reinvestigated compressibility problems using a newer version of the high speed wind tunnel. What they found was that passed the critical velocity of an airfoil the air flowed as expected over the first ⅓ to 2/3 of the wing, but after that distance there was a sudden jump in pressure followed by an area of low pressure. From the data collected Briggs and Dryden hypothesized that something was causing the flow pattern over the airfoils to be separated into disorganized areas of turbulence, causing excess friction. The two later proved their hypothesis using a widely accepted method of flow-separation detection (Anderson, n.d., para. 25-29).

In 1934 the reason behind the turbulence was revealed when John Stack of the National Advisory Committee for Aeronautics (NACA, the predecessor of NASA) obtained a schlieren photographic system, a scientific instrument that allows pressure differences to show up as visible marks on photographs. On a hunch John Stack ran an airfoil up to its critical velocity and then took a picture using the schlieren system. The result was the photograph seen in figure 1. From the photographs it was discovered that as air moves around an airfoil the speed increase is enough for it to break the sound barrier, making a shockwave capable of disorganizing the supersonic airstreams (Anderson, n.d., para. 45-48).

![Figure 1. Part of the original picture John Stack took using a Schileren photography system with some markings added for ease of recognition. The red marks indicate where the shockwaves, seen as a rippled area of slightly lighter color, are located. The airfoil is the darker teardrop shape in the middle of the picture (outlined in strong black).](image-url)

In the early 1940s American aeronautical engineers began to implore the government to fund a supersonic plane build entirely for the investigation of compressibility problems. The original proposal made by NACA called for a small turbojet powered aircraft capable of taking
off under its own power and flying at a maximum speed of mach 1. NACA wanted the plane purely for research purposes, but when the army offered its funding it required the plane to break the sound barrier under rocket power after being launched from a B-17 bomber. The plane, designated the X-1, was contracted to the Bell aircraft company and test flown for the first time on October 14, 1947. Despite a broken rib, the pilot, Charles Yeager managed to break the sound barrier on his first flight, proving that a plane could break the sound barrier without becoming uncontrollable (Anderson, n.d., para. 62-82).

The Components of a Jet Engine

However, the future of supersonic flight would be through gas turbine engines (jets) rather than rockets. Jets generally have four major components known as the compressor, combustion chamber, turbine, and nozzle, but different variations of the engine often have additional systems. A basic jet works by channeling oncoming airflow into a compressor, or a set of blades that increases the pressure of the gases in an engine by forcing them into spaces of lower volume. There are two kinds of compressors: centrifugal and axial. Axial compressors tend to be more efficient, but centrifugal compressors are still common. After being compressed, the air is then laced with gasoline and exposed to an electrical spark inside the combustion chamber, causing a chemical reaction. The heat produced then causes the air to expand, increasing its pressure. The high pressure causes the air to travel from the combustion chamber with a high velocity and though a turbine, a section of blades connected to the central shaft that drives the compressor. The turbines convert part of the kinetic energy in the airflow to mechanical energy for use in sustaining the compressed airflow into the engine. After passing through the turbine, the still forceful gases exit out a specially designed opening known as the nozzle that increases the velocity of the gases, propel the plane forward using Newton’s third law (NASA, n.d., para. 5-10).

Different Engine Designs

As stated above, there are some types of engines that modify this basic design and these are the turboprop, turbofan, ramjet, and turboshaft. Turboprops are the most efficient of the alternatives at speeds lower than Mach 0.6, and produce their propulsion by pulling, rather than pushing, the engine through the air. In a turboprop most of the kinetic energy in air flowing through the engine converted to mechanical energy in the turbine section, powering a propeller added to the end of the central shaft. Of these, the turbofan is the most popular today and is used by almost every aircraft for traveling speeds between Mach 0.6 and 1. Turbofan engines work by propelling a large amount of gas at a low speed while other jet engines accelerate very little gas to very high velocities. The ramjet is the simplest of the engine designs because it is simply a combustion chamber because at high speeds the shape of the engine compresses the air. Despite its simplicity, ramjets are only useful at speeds greater than Mach 3. Finally, jet engines have also been adapted to power helicopters in the turboshaft engine. Turboshafts are essentially reorganized turboprop engines capable of removing the dust and debris common at lower altitudes (Hünecke, 1997, pp. 7-14).
Future Applications

Jet engines show signs of future promise as the technology branches out to applications other than transportation. Scientists have studied fuel cells for years as a clean source of portable power; however, Engineering students at the Massachusetts Institute of Technology (MIT) have developed a miniature jet engine the size of a computer chip that they envision powering portable devices or even cities. Alan Epstein, the professor overlooking over the project, sees the microturbines entering the market within a year, first for soldiers and then for consumers. While fuel cells are very specific in the fuels they use, a micro-turbine will burn just about anything and produce between one to twenty times more power than its fuel cell competitors (Freedman, 2004, para. 1-11).

Literature Cited


Chapter 11

Airplanes

History of the Invention

The airplane is an invention in history that will always be remembered as being an important advancement in technology. Nearly 107 years ago, two famous brothers known as Wilbur and Orville Wright invented the airplane. Before the first flight, model airplanes had been built and studied and then a basic construction of a prototype took place. The Wright brothers studied these models, and in 1903 Wilbur and Orville Wright of Dayton, Ohio, completed the first four sustained flights with a powered controlled airplane, which had never been accomplished before. They had opened a new view into what can be accomplished from their discovery and invention of flight. Airplanes would allow people to travel great distances, people would begin to improve designs of prototypes, and airplanes would even bring warfare to the next level.

In 1903, the airplane was invented to prove a point and achieve a goal the Wright brothers had: the ability to fly. They never thought about the possibilities that would be born from this invention. The first look at the use of airplanes was during the years of 1914-1918, World War I (WWI), only ten years after the first flight of a basic biplane design (Ilan, n. d. para. 1). Other than the desire for higher speed, higher altitude, greater maneuverability drive during WWI, there were dramatic improvements in aerodynamics, structures, and control and propulsion system design. This was the first time when airplanes were used for warfare. Even before planes were used for war purposes, they were used as aerial scouts, which are planes that spy on the enemy from the sky (Ilan, n. d. para. 4). On October 14, 1914 a French scout mounted a rifle to a spy plane, thus creating a plane classification known as the fighter warplane (Ilan, n. d. para. 4). Next, rifles were mounted onto airplanes and hand grenades were dropped from the plane. Soon, three major roles were defined for aircraft during the First World War: reconnaissance, bombing, and fighting. Promptly, an aircraft was designed for each need: reconnaissance planes some armed for defense; fighter planes, exclusively designed for shooting down other planes; and bombers carried more immense loads of explosives. Aircraft in WWI showed what could happen, although air power proved inconsequential and had no real affect on the outcome of the war, but did spark a new interest in technology and science.

Basic Science

The science behind how airplanes work is classified into four basic aerodynamic forces: lift, weight, thrust, and drag (Brain, 2000, para. 2). Each of these three categories can be explained in much detail to completely understand how an airplane flies. What must be understood is that the amount of thrust force must equal the amount of drag, and the amount of lift force must equal the amount of normal force or weight (Brain, 2000, para. 2). If this is true, then the plane will remain in equilibrium. Otherwise, if the amount of drag becomes larger than the amount of thrust, the plane will slow down. If the thrust is increased so that it is greater than the drag, the plane will accelerate (Brain, 2000, para. 3). How these forces are created is the next
question. Airplanes create thrust using propellers, jet engines or rockets. Drag is an aerodynamic force that resists the motion of an object moving through a fluid. Lift is the aerodynamic force that holds an airplane in the air. A fluid is defined as a mixture of numerous of gases, including nitrogen, oxygen, water vapor carbon dioxide, argon, and trace amounts of other noble gases. Therefore, air is considered a liquid.

The lift coefficient of an airfoil is a number that relates the lift-producing capability to air speed, air density, wing area, and angle of attack (the angle at which the airfoil is oriented with respect to the oncoming airflow) (Brain, 2000, para. 7). However, there are two different methods and explanations of lift. The two theories both have pros and cons to their explanation. The theories are known as the longer path explanation (also known as the Bernoulli or equal transit time explanation) and the Newtonian explanation (also known as the momentum transfer or air deflection explanation) (Brain, 2000, para. 8). The longer path explanation describes that the air particles evenly hit the top surface of a wing that is more curved and the bottom surface of a wing; this will keep the plane aloft in the air. However, the Newtonian law explains that the particles hit the bottom of the wing, causing the plane go higher and the particles bounce off the wing in the opposite direction. This is a direct example of Newton’s third law that states for every action force there is an equal, and opposite, reaction force. The Wright brothers were the first to test these forces, and obtain live data using limited technology of that time period.

Technology

In 1902, Wilbur and Orville Wright had limited technology for calculating values compared to what is available for use today. They began with many fundamental tests regarding aerodynamics in a wind tunnel during the winter of 1901-1902 (“First-to-Fly,” n.d., para. 2). No one before the young inventors checked their data against the performance of an aircraft in flight, meaning that the Wrights were the first to verify laboratory results with actual flight tests.

The Wright brothers used trigonometry and angles rather than vector analysis, which is commonly used today. They used a long string that would be connected to the airplane and the ground to act as the hypotenuse of the triangle and looked at the forces of lift and drift as the legs of a right triangle (“First-to-Fly,” n.d., para. 7). The Wrights could find any part of the lift-drag triangle as long as they knew the magnitude of one part and one of the angles between the hypotenuse and another part. The lower the lift or the higher the drag, the greater the angle of the rope as measured from the vertical (“First-to-Fly,” n.d., para. 7).

The brothers also made calculations pertaining to the pressure of air on the wing of the airplane. They investigated the coefficient of pressure known as Smeaton’s coefficient, which was first derived in 1759 (“First-to-Fly,” n.d., para. 8). This states that the amount of pressure generated is proportional to the size of the sail and the velocity of the wind. Smeaton multiplied the surface area times the square of the wind velocity, and then devised a multiplier to convert the result into pressure. After obtaining live data, the lift and the drag of each foil was plotted against the angles of attack, and they were able to observe and compare the efficiency of the wing shapes. From this data, they wanted to find an efficient wing shape, one that would produce the most lift and the least drag. After taking over 2,000 flights, in 1902, the Wright glider was the first flying machine the brothers designed using their own data, and it was the first to actually produce the predicted lift (“First-to-Fly,” n.d., para. 10).
Inventors and Contributions

In late autumn of 1878, the Wright brothers’ father brought home a mysterious object that was concealed in his hands, but before the brothers could make out what the object was their father tossed it into the air. Instead of what the brothers predicted, (the object falling to the floor) it flew across the room until it collided with the ceiling, where it fluttered awhile, and finally fell to the floor (Wright, 2008, para. 1). The little toy was known as a "helicoptere" by scientists; however, the Wright brothers renamed it a bat because of how it flew across the room resembling the flight of a bat (Wright, 2008, para. 1). Ever sense their first experience with the flying toy, the Wright brothers were determined to come up with a model that was much larger, but little did they realize that the larger model would require much more power and thought. They were young at the time, and enjoyed playing with kites, but they wanted to take their passion for flying to the next level. When the Wright brothers knew of the sad death of Lilienthal that reached America in the summer of 1896, they paid more attention to the subject of flying (Wright, 2008, para. 3). The brothers had great interest and studied several sources pertaining to early advancements and research of flight. A few examples they were interested in were the following: Chanute's "Progress in Flying Machines," Langley's "Experiments in Aerodynamics," the "Aeronautical Annuals" of 1905, 1906, and 1907, and several pamphlets published by the Smithsonian Institution, and especially articles by Lilienthal and extracts from Mouillard's "Empire of the Air" (Wright, 2008, para. 3). Mouillard and Lilienthal were great missionaries of the flying cause, and they inspired Wilbur an Orville to transform their curiosity of flying into a reality. During the period from 1885 to 1900 there was unexampled activity in aeronautics, and for a time there was high hope that the age of flying was at hand. There were many tests recorded and conducted with flight, and many lives were taken from completing these tests.

As the Wright brothers began testing their model planes in October 1900, at Kitty Hawk, North Carolina, their first design was of the kite type, where it was designed to take off in winds from 15 to 20 miles per hour with one man on board (Wright, 2008, para. 4). They had not done any measurements or calculations before the flight; therefore, it did not function properly. The Wright brothers were motivated to continue with their work, and began making some very important contributions to the science, technology, and history of flight. The young inventors came up with the very first airplane design that could glide in the air, and there were calculations that proved their results. “In September and October, 1902, nearly 1,000 gliding flights were made, several of which covered distances of over 600 feet” (Wright, 2008, para. 4). They also were the first to come up with a successful power-flyer, and the first flights with the power machine were made on December 17, 1903 (Wright, 2008, para. 4). Without what the brothers accomplished 107 years ago, the technology and understanding of airplanes would not be as advanced as they are today.

Impact on History

The airplane had a large impact on history, mainly for the better. From the beginning of flight, it was known by the great inventors of the time that there was always going to be a continual improvement and advancement to the design, technology, and understanding of airplanes. After the airplane was invented and patented, there were endless opportunities to be the first to do any particular event with an airplane. Seven years after the first flight, Eugene Ely
pilots a Curtiss biplane on the first flight to take off from a ship (“The history of flight”, n.d., para. 2). This idea impacted the way some airplanes today are transported and used for military purposes. Nine years after the first flight, airplanes were used during World War I. The requirements of higher speed, higher altitude, and greater maneuverability drove dramatic improvements in aerodynamics, structures, and with control and propulsion system design. Other than the desire to use airplanes for defense, the U. S. Postal Service inaugurated airmail service from Polo Grounds in Washington, D.C., on May 15 (“The history of flight”, n.d., para. 5). This sparked the idea of using flight to transport goods and valuables from one location in the world to a distant location, perhaps transcontinental, or transatlantic. Airplanes have evolved from a dream, to an idea, to a concept, and finally to a reality. The Wright brothers only had the intent to prove that it was possible to make Mouillard and Lilienthal's ideas a reality; they did not expect airplanes to become the next largest mode of transportation, exploration, and military defense. Presently, airplanes are used to simulate what it is like to float in space with little gravitational force, something that the Wright brothers would have never thought to be plausible.

Extensions of the Invention

It is evident that the airplane had endless extensions and future applications after it was first patented. The first flight was proof that it was possible to fly in the air, for what is considered today, a reasonably short amount of time. When the invention was studied and researched, airplanes were soon the biggest focus of improvement and extensions. It seemed as if everyone was trying to make it into history for performing something with an airplane that has never been done before; and there were many possibilities, almost seeming endless. However, as the years progressed, it seemed as if people were running out of ideas to do with airplanes. Therefore, the technology and understanding of airplanes became more complex and in depth. For example, in 1969, the first man had stepped foot on the moon. This proves that many different applications, studies, and research had been developed from the very simple and basic concept of the Wrights first gliding and powered airplanes.

Presently, there is research being done and studies being completed to further the technology and overcome goals that the Wright brothers would have never imagined. However, there are some basic features that have been around for a while because they have proved reliable in the past years. For example, the exterior design of the airplane has not changed in the last 40 years, and researchers will use previous history to make refinements (Wise, 2006, para. 1). Some may ask, what is keeping the development of new aircraft bodies from advancing? The answer is a huge economic risk and a liability risk, which is a great concern to U.S. manufacturers of small aircraft. Technology has been evolving over the years, just as the airplane has, and now the two topics are being fused into one focus to make advanced aircraft of the future.

The plans for the future seem nearly impossible and far from achieving, but the ideas are more realistic than it would have been hundreds of years ago. An example of an evolutionary improvement is where the reduction in cost will be a factor of three (Wise, 2006, para. 1). Even though the appearances of the airplane will remain similar, there will be a great reduction in price, namely through improvements in aerodynamics, structures and materials, control systems, and (primarily) propulsion technology. In the past 40 years, airfoil design has improved dramatically. It started from the transonic "peaky" sections used on aircraft in the 60s and 70s to the more aggressive supercritical sections used on today's aircraft (Wise, 2006, para. 2). Propulsion is the area in which most evolutionary progress has been made in the last few
decades, and it will continue to improve the economics of aircraft (Wise, 2006, para. 3). The need of clean, low cost, and low noise engines is growing for aircraft ranging from commuters and regional jets to supersonic transports. There are different designs that NASA has been developing to structurally improve passenger cargo, the stability of the aircraft, and supersonic travel (Wise, 2006, para. 3). The structure is also evolving rapidly, along with the materials used in creating the aircraft. Composite materials are finally finding their way into a larger fraction of the aircraft structure, but not for commercial airlines. However, in the next ten to twenty years the airlines and the FAA will be more ready to adopt this technology.

The development of the airplane has clearly evolved over the past 107 years, from the first flight of the Wright glider and powered airplanes. The invention was researched by many scientists and engineers of the past, but was put to the test by Wilbur and Orville Wright. They were the first to fly, the first to use technology, and take tests that were analyzed and used in real life. They had basic technology to complete their work, and over the years, technology improved vastly. Today, without airplanes, it would not be possible to have a world like there is today. It is a world with a powerful military, a mode of transportation, and exploration. There remains many extensions to this invention, and without the basic idea of flying the Wright brothers invented, the science of aviation would not be as advanced and detailed as it is today.

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Chapter 12

Mechanical Clocks

Introduction

The mechanical clock, along with all other types of clock, has had a tremendous impact on history. Countless scientific experiments required a stopwatch, which means that many great discoveries would not have come to be should the clock have advanced no further than the sundials of the past. Schedules require knowledge of time in order to work; hence, anything that is scheduled, such as planes or workdays, would be rendered ineffective. It is difficult to imagine a business that starts at sunrise, one of the few positions of the sun that is easy to distinguish from others, and ends when the sky begins to show stars as conducive to attentive and efficient employees. The clock has helped keep everything organized.

Mechanical clocks were not the first mechanisms for monitoring time. Consisting of a vertical shaft casting a shadow opposite the direction of the sun, the sundial was among the original time measuring devices due to being simple and effective. A person could then read the time based on the orientation of the shadow. Because of the simplicity and ease of use, the sundial remained widespread in America far into the nineteenth century. One lasting impact of it is that modern timepieces rotate clockwise because the shadow cast by a sundial rotates clockwise in the northern hemisphere. The design was flawed because it required sunlight to function; hence, it was rendered useless whenever the weather was overcast or the sun had set. Also, as the year progresses, the length of time the sun is overhead varies; this phenomenon causes the hours that a sundial shows to become shorter and longer on different days. The ancients needed a different design, one that overcame the problems of the sundial, which meant that the search had begun for a device that did not measure time according to the position of the sun.

The search ended after the discovery that water in a bowl would flow through an opening at a reasonably steady pace. This new apparatus was the clepsydra, and it became widespread throughout Babylon and Egypt during the time of the Middle Kingdom (Usher, 1988, p. 142). They are still in use today in the form of hourglasses. While it is unknown how accurate they were, historians believe that they were inadequate compared to modern standards, but that the ancients were not as concerned with exact time because of the slower pace of travel (Marrison, 1948, sec. 2 para. 9). Hero of Alexandria and Vitruvius both wrote about the types of clepsydra that existed during their respective lifetimes. Hero stated that some of the devices powered a complicated series of mechanical statues and auditory signals to state the time (Usher, 1988, pg. 144). They required a large amount of maintenance because of their constant need to be refilled with water or, if water were scarce, sand. The clepsydra and sundial dominated the design of clocks without any major improvement on their shortcomings for thousands of years.

Eventually, in the 900s AD, new ideas for improving the accuracy of timepieces came to fruition. Some of the less practical solutions were candles and lamps that burned at a predictable rate (Marrison, 1948, sec. 2, para. 10). They offered a better sense of time while providing their
own light; however, they failed to work when not placed in a dry location and cost too much due to their limited ability to be reused. The inherent drawbacks led these types of designs to be impractical for those with a limited expendable income.

The most practical type of clock that is recorded to have existed during the nine hundreds was driven by falling weights. Although the device was little better than the clepsydra in terms of accuracy, it could be made to fit within smaller dimensions (Marrison, 1948, sec. 2, para. 9). Coiled springs had similar effects to falling weights but required an even smaller area (History of Time, n.d., para. 6).

The methods for using falling weights improved slowly over time without any major addition until the invention of the escapement by Henry de Vick around the 1360s (Marrison, 1948, sec. 3, para. 1). The escapement is a device that uses a continuously rotating gear to create an oscillating motion, which, in the case of a clock, would then be used to measure time. This new design still depended on falling weights to function, and therefore suffered from the same inaccuracies of the clocks before it, as evidenced by their inability to use anything more detailed than an hour hand. However, the use of oscillation to control a clock was a revolutionary idea and would become more important further along in clock development. The use of escapements became a standard across Europe soon after their introduction, particularly within the clock towers that regulated the work hours of the many industrial towns within the northwest. Interestingly, an original escapement clock that was created by Henry de Vick is still in use, albeit heavily modified, outside the Palais de Justice in Paris (Marrison, 1948, sec. 3, para. 1). The development of clocks that utilized oscillation allowed for an unprecedented leap in accuracy after the next great development: the pendulum.

The pendulum operates on a simple concept: a swinging weight can be used to measure time. In the modern age, physics has proven that a pendulum will take the same time to swing from the left to the right regardless of the angle of the beginning position (so long as it is less than fifteen degrees); however, this concept was not noticed before the seventeenth century. There is a possibly apocryphal story that around 1583, Galileo Galilei, using his pulse as a timer, noticed the chandelier in the Cathedral of Pisa took an invariable amount of time to complete a full swing when swaying. Supposedly, he performed more research and sixty years later told his son, Vincenzio, that the pendulum had untapped potential for timepieces (Marrison, 1948, sec. 4 para. 13). Because of the lack of pendulum clocks during the time, the story is dubious; yet, it is clear that the pendulum existed in 1657 because it was written about by the inventor, Dutch scientist Christian Huygens, in a book published in 1658 (Marrison, 1948, sec. 4, para. 13).

As a testament to the improved accuracy of the pendulum, little is known about the types of mechanical clocks before 1658 because almost all of them were upgraded to include a pendulum (Marrison, 1948, sec. 4, para. 14). Theoretically, a pendulum should swing forever; this is not the case in reality because friction slowly degrades the swing. Huygen realized that using a weight to push the pendulum down at the top of the swing could, by applying enough force, neutralize the effect of friction. The pendulum made it possible to keep accurate time; in turn, the populace began to rely on accurate times within their daily lives.
While in the past improvements to clock design had always been slow because of the lack of need, at this point, a demand for more accurate devices spurred the development of many improvements. The temperature of the air would cause the pendulum to expand or contract, which would cause a minor variation in the length of a second. A minute problem in the age of the clepsydra, it became a difficult challenge for clockmakers of the day, who tried everything from the altering of pendulum lengths according to temperature to the creation of a new alloy which had a very small expansion rate (Marrison, 1948, sec. 4, para. 26). Pendulum clocks were made to be accurate, which gave people and governments the ability to consider solving problems by measuring time. Most of the development of clocks had come from a general need for accuracy; however, there was a substantial series of improvements that were introduced by one man’s response to a competition held by the English Parliament.

For the pilot of a ship, knowing exactly where the vessel is in the world is important. Since medieval times, the astrolabe had made latitude simple to find. The astrolabe would give the angle of the sun relative to the gravity of the earth, which could be used to find the latitude one was traveling. Unfortunately, the longitude could not be determined by the sun or stars. The people of the time realized that there were time differences between cities. For example, Los Angeles is three hours behind Boston. After experimentation, they determined that if the time in two different locations were known, then the longitude of one relative to the other could be found. It was always possible to find when it was noon on a ship, but in order to find longitude, one needs to know the time at a standard location (which was generally Greenwich). The trouble was that the clocks used to tell the Greenwich time were rendered useless because the swaying motion of the boat would prevent a pendulum clock from operating properly, and non-pendulum clocks were not accurate enough on land, let alone the sea (Fernie, 2003, para 2).

John Harrison, an English clockmaker, spent seventeen years creating many different clocks until he arrived at a design that worked impeccably well, which was later christened the H4 (Fernie, 2003, para 9). Designed like an oversized pocket watch, the H4 introduced innovations like using diamond to create a nearly frictionless environment, using different metals in harmony to oust the temperature problem, and creating a winding mechanism that did not interfere with the clocks movement. The H4 did not have a revolutionary new design, but it had a revolutionary redesign of many of the inner workings of clocks. It was tested and found to be only a few seconds off after a trans-Atlantic voyage, but humans have continued to demand more accurate machines (Fernie, 2003, para 9).

The need for extremely accurate clocks was completely fulfilled in the twentieth century. In 1967, a clock that based the time on the degradation of cesium-133 became functional (History of Time, n.d., para 11). It will take another 1.4 million years before it is a second off the actual time. In 1999, an even better version was introduced that will operate for twenty million years before losing a second (History of Time, n.d., para 11). There is nothing humankind can do that would require that amazing accuracy; therefore, the development of clocks has halted in terms of functionality. There are new and weird watches that are entering the market which experiment with the presentation of the time, but these are not improvements as much as they are a change in fashion.
Clocks have been impacted by history and have impacted history. Einstein conceptualized the theory of relativity while riding away from a clock tower. However, the clock has never been a driving force of society; instead, it has been developed independently of the culture and then scientists, businesses, and average citizens have always found a need to utilize the most accurate timepiece to the full potential.

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Chapter 13

Dynamite

Introduction

Attempting to create a safe explosive in 1846, Ascanio Sobrero carefully heated a drop of nitroglycerine, a compound derived from heating glycerol with concentrated nitric and sulfuric acid, in a glass test tube. Suddenly, the drop exploded and sent glass fragments flying into Sobrero’s face and hands, which scarred him for life (Cotton, n.d., para. 3). Sobrero, who initially wanted to use the explosive for peaceful purposes, destroyed his notes to keep his invention a secret (“People and Events”, n.d., para. 1). However, the discovery of the explosive could not be kept quiet for long; Sobrero’s invention was soon discovered and tested for its military and commercial applications (Cotton, n.d., para. 3). When Charles Crocker and James Strotbridge shipped nitroglycerine crates to a construction company in San Francisco in 1866, the crate exploded resulting in the death of 15 people. Outraged with the catastrophe, the Californian legislature confiscated all private stocks of nitroglycerine and banned its transportation within the state (“People and Events”, n.d., paras. 1-4). When Alfred Nobel attempted to stabilize nitroglycerine, he succeeded in producing a powerful yet safe explosive that he named dynamite. Nobel’s invention revolutionized the world as dynamite had myriad applications in fields ranging from construction to national defense.

Science behind Explosives

Nitroglycerine and dynamite are considered chemical explosives because they release a large amount of hot gas when ignited. The gas holds a large amount of thermal and kinetic energy which allows it to expand rapidly and exert tremendous pressure upon objects exposed to it. In addition to applying pressure, the gas rapidly heats all objects within the blast radius of the explosion, the distance from the explosive to the farthest point where objects are still affected by the explosion. This combination of heat and pressure causes objects within the blast radius to incinerate (“What is Dynamite”, 2000, para. 1).

Explosives are categorized as either being High Explosives (HE) or Low Explosives (LE). The difference between HE and LE is their power level; while Low Explosives deflagrate, High Explosives fully detonate. A substance is said to deflagrate when it burns rapidly and detonate when it combusts faster than the speed of sound. Because deflagration is slower than detonation, Low Explosives release their potential energy in a larger span of time than High Explosives. Therefore, according to the power equation \( \varphi = \frac{\Delta \text{Energy}}{\Delta \text{time}} \), High Explosives are much more powerful than Low Explosives (“Military Explosives”, 2006, paras. 1 – 3).

Black Powder

Approximately 1000 years ago, Chinese alchemists discovered the secret to producing explosives. They heated a mixture of charcoal, sulfur, and saltpeter (potassium nitrate) to produce a black porous powder that they named black powder. The Chinese used black powder primarily for entertainment purposes; however, when Europeans were introduced to black
powder, they used the dangerous powder to power lethal projectile weapons. The introduction of black powder to military technology revolutionized battle tactics and strategy. The castle, which was used as an impenetrable stronghold before the invention of black powder, was rendered virtually useless because attacking armies could easily destroy castle walls with black powder. However, black powder had its limitations as well. Because black powder was not powerful, a large amount needed to be synthesized for effective use in war. Therefore, military commanders only used black powder in dire circumstances because synthesizing and transporting the explosive was a drain on resources that could be used to better outfit their army (“Explosive History”, n.d., paras. 1-3).

Nitroglycerine

During the Industrial Revolution, there was a need of a powerful explosive that could be used to clear otherwise uninhabitable areas for infrastructure development. Because black powder was not cost effective, European governments heavily encouraged scientific research to produce powerful yet relatively cheap explosives. In 1846, Ascanio Sobrero, a professor of chemistry in Turino, Italy, succeeded in synthesizing nitroglycerine. However, nitroglycerine was exponentially more powerful than black powder; therefore, Sobrero, believing that nitroglycerine could never be used as a safe explosive, kept his invention a secret (“Ascanio Sobrero”, n.d., para. 1-2). In its natural state, nitroglycerine is a yellow, oily liquid that is chemically unstable. Nitroglycerine starts to lose stability and become volatile at 100 degrees, shows signs of nitrous gas formation at 135 degrees, and explodes at 218 degrees. The chemical formula for nitroglycerine is $\text{C}_3\text{H}_5\text{(ON}_2\text{)}_3$ (Budavari, Maryadele, Smith, & Joanne, 1996, p. 6705).

Nitroglycerine is an extremely powerful explosive because each molecule contains the oxygen required to oxidize the carbon and hydrogen. This allows the explosion to take a lower amount of time, which vastly increases the power of the detonation (Gardner & Sloane, 1939, p. 328). However, because pure nitroglycerine was very unstable, scientists during the industrial revolution soon learned that unless nitroglycerine was reacted with another substance to form a stable compound, then it was too dangerous to use for any peaceful purpose. For this reason, very few scientists even had the courage to experiment with nitroglycerine; however, one such scientist who was determined to produce a safe explosive was Alfred Nobel (“People and Events”, n.d., paras. 3-4).

Alfred Nobel and Dynamite

Alfred Nobel’s interest in military technology was fostered largely by his father, Immanuel Nobel, who was an inventor and entrepreneur for the Russian Military Department. Immanuel Nobel highly valued education; consequently, he hired Russian tutors to teach his children science, specifically chemistry, and a variety of other subjects. When Alfred Nobel was 16, Immanuel Nobel sent him to travel Europe and work with some of the most famous scientists of the time. When he went to Paris to work in the laboratory of Théophile Pelouze, Alfred Nobel met Ascanio Sobrero. It was here that Nobel was first introduced to nitroglycerine. When he returned back to Russia after the end of the Crimean War, Nobel found that his father’s company was forced to declare bankruptcy due to their enormous overheads and low revenue. Alfred
Nobel, who was specifically directed to never experiment with nitroglycerine by Sobrero, decided to open up a nitroglycerine manufacturing plant along with his brothers ("Nobel", n.d., paras. 1-3).

Nobel had to pay dearly for not listening to Sobrero’s device. In 1862, there was an explosion in his manufacturing plant causing the death of his youngest brother, Emil Nobel. Alfred Nobel, traumatized by the explosion, immersed himself in conducting research towards stabilizing nitroglycerine. Essentially, Nobel was searching for a substance that would absorb and stabilize nitroglycerine without modifying its explosive properties. He soon found that a mixture of nitroglycerine and diatomaceous earth, also known as kieselguhr, formed a powdery substance that exploded when exposed to a strong charge; Nobel named his substance dynamite ("Alfred Bernhard Nobel", n.d., para. 3).

Dynamite acts as a HE and is nearly as powerful as pure nitroglycerine. In his patent for dynamite, Nobel proposed many different recipes for dynamite depending on the requirements of the final mix. He recommended a 75:25 nitroglycerine to earth ratio (by mass) for a general dynamite powder, a 60:40 ratio for minimum strength dynamite powder, and a 78:22 ratio for maximum strength dynamite powder (Nobel, 1868, 78317). Even today, dynamite is generally mixed with a 75:25 nitroglycerine to earth ratio (Gardner & Sloane, 1939, p. 329).

Dynamite Technology and Applications

After patenting dynamite powder, Nobel invented a safe, cheap, efficient storage means for his dynamite powder. He encapsulated the powder in a cylindrical device with a blast cap mechanism and a fuse charge (see figure 1).

![Diagram of Nobel’s device for encapsulating dynamite powder](image)

This is a diagram of Nobel’s device for encapsulating dynamite powder ("Picture Game", n.d., para. 4).
The blast cap mechanism was a mechanism that was designed to detonate a stick of dynamite while using the least amount of force possible. First, a charge would be sent blast cap through the fuse, which would result in a minor explosion. The minor explosion would in turn have enough energy to fully detonate all the dynamite powder within the stick ("Alfred Bernhard Nobel", n.d., paras. 2-3). Nobel’s blast cap mechanism allowed for long-distance detonation as well, because even if the majority of the charge on the fuse was lost while traveling to the blast cap, the remaining charge would generally be enough to explode the blast cap; this method made dynamite very safe to explode and work with. Many scientists today believe that after the invention of black powder, Nobel’s invention of the blast cap was the most important discovery in the field of explosives ("Explosive”, 2009, paras. 29-30).

The discovery of dynamite may have been the most important discovery in the Industrial Revolution. At this time, miners and quarry workers had little to no access to power machines and other powerful technological devices. Dynamite allowed such workers a simple way to destroy mines and rock to use for materials or clear for further industrialization. The Department of Defense replaced black powder with dynamite, granting the military an exponential increase in power ("Military Explosives, 2006, paras. 1-2).

In addition to using dynamite for static explosions, the military applications for dynamite are virtually endless. In the 1900s, military departments began conducting significant research analyzing potential applications of dynamite in the military. The modern grenade launcher is stemmed from a military test done in which dynamite was loaded into an artillery weapon and fired over to enemy quarters. This mechanism was known as a dynamite gun, and while the gun itself was deemed too expensive to use, the concept of the gun still helped create a new niche in the weapons industry, grenades.

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Chapter 14

The Navigational Compass

History

Before the navigational compass, navigators implemented several other devices in order to navigate the world. The most common method of navigating was by use the stars. Sea captains and some select members of the crew used a device called a sextant to determine their current location relative to the stars. This strategy, like most others of its time, had some fundamental flaws. This method was useless under cloudy or hazy conditions. The navigators needed a clean view of the sky in order to determine their location. As a result, ships and crews of men often ended up being lost at sea for weeks at a time. It was clear that some sort of tool was needed to improve navigation (Moody, 2007, para. 3).

The first type of compass to be invented was the magnetic compass. It is said that as early as the twelfth century A.D., the Chinese used magnetic compasses for navigation at sea, and on land much earlier. Until the twentieth century, the magnetic compass was the prominent tool for navigation. However, in 1908, Han Anschutz invented one of the first modern gyrocompasses. Instead of relying on the earth’s magnetic field, the gyrocompass utilized the rotation of the earth in order to determine the location on the surface (History of the navigational compass, 2009, para. 5).

Exploration

The first large impact that the navigational compass had on the world came around the late fourteenth century. It was during this time that the Age of Exploration began. Civilized people had frequently traveled in boats and across land to trade with members of other societies, but these excursions were never for the sake of exploration. After the invention of the magnetic compass, countries began sending boatloads of explorers and sailors to all corners of the world. The Spanish, Portuguese, English, and French would end up dividing up all of North and South America among themselves, while Africa was left to be imperialized by nearly every coastal country in Europe (Compass Navigation, 2009, para. 2).

The Age of Exploration essentially introduced the various types of people in the world to each other. It allowed for unique trading and for unique technologies to be developed. The vast amount of wealth that would be brought to Europe during this time period helped fuel the Enlightenment and Industrial Revolution. Without the invention of the navigational compass, it is likely that this historic time period would not have been nearly as influential on people around the globe (Compass Navigation, 2009, para. 4).
Magnetic Compass

There are two basic types of magnetic compasses, those with the dry card and those with the liquid. The dry-card compass used on ships consists of a system of magnetized needles suspended by silk threads from a graduated card about 25 cm in diameter. The magnetic axes of the needles are parallel to the card’s north and south graduations. There is a sharply pointed pivot at the center of the card. Sitting on the pivot is a fitted cap with a jewel bearing. The point of support is above the center of gravity of the system, so that the card always assumes a horizontal position (Cannon, 2008, p. 4).

The lodestone is a magnetite with a particular crystalline structure that enables it to act as a permanent magnet and attract and magnetize iron. The naturally occurring lodestones are magnetized by the strong fields surrounding lightning bolts. In fact, the name magnet comes from the naturally occurring lodestones which are found in Magnesia, a portion of ancient Thessaly, Greece (Marshall, 2008, para. 4).

A liquid compass is slightly different. It is mounted in a sealed bowl filled with a liquid of low freezing point. The buoyancy of the card is adjusted so that it floats in this liquid. This ensures the minimum possible friction between the cap and pivot. When there is friction between the card and picot, it causes the direction of the compass to be slightly less accurate (Williams, 1992, p. 2).

At first, the magnetic compass seemed to be sufficient for explorers and navigators. It was accurate and it got them from place to place. However, as technology became more and more sophisticated, humans began to move away from wooden vessels and towards metal ones. Most metals, unlike wood, disturb a magnetic compass because the magnet within the compass is slightly attracted to the other metal substance nearby. This causes the direction of the compass to be slightly altered. Another blow was dealt to magnetic compasses when ships began to generate their own magnetic fields because of their onboard radios. These other fields interfered with the magnetic field of the earth and could sometimes cause the compass to go haywire (Moody, 2007, para. 8).

Another problem with the magnetic compass is that it does not provide a traveler with exact north, because the magnetic axis of the earth is slightly different from its axis of rotation. Some compasses attempt to account for this change, but the difference varies depending on their location on the surface of the earth. The only way to solve this slight issue is to study the sea or land charts (Cannon, 2008, p. 3).

Gyrocompass

In order to solve most of these problems, a new device, the gyrocompass, was invented. The main difference between a gyrocompass and a magnetic compass is that a magnetic compass relies on the magnetic field while a gyrocompass relies solely on the rotation of the planet. A gyrocompass combines the activation of two devices, a gyroscope and a pendulum, in order to produce alignment with the spin axis of the Earth. Essentially, the gyrocompass consists of a
rapidly spinning, heavy gyro rotor, a pendulous case that allows the axle to nod up and down, and an outer gimbal which permits the axle to rotate back and forth (Cannon, 2008, p. 1).

The magnetic compass has been largely replaced by the gyrocompass, which is not subject to variation or deviation, as the primary source of directional information at sea. However, the magnetic compass which does not require an external source of electric power and does not have a mechanism subject to failure, is still standard equipment aboard ships, and small craft almost universally uses the less expensive magnetic compass exclusively (Cannon, 2008, p. 2).

Compass Rose

The compass rose has been on charts and maps since the fourteenth century. The term rose derives from the compass points resembling the petals of the flower. Originally, this device was used to indicate the direction of the winds, so the 32 points of the compass rose come from the directions of the eight major winds, eight half-winds, and sixteen quarter winds (Thoen, 2001, para. 2).

There is no standard for drawing a compass rose, and each school of cartographers seems to have developed its own. In the earliest charts, north is indicated by a spearhead above the letter T (for tramontana). This symbol evolved into a fleur-de-lys around the time of Columbus, and was first seen on Portuguese maps. Also in the 14th century, the L (for 84evanter) on the east side of the rose was replaced with a cross, indicating the direction to Paradise (long thought to be in the east), or at least to where Christ was born (in the Levant) (Thoen, 2001, para. 3).

The colors on the figure are supposedly the result of the need for graphic clarity rather than a mere cartographical whim. On a rolling ship at night by the light of a flickering lamp, these figures had to be clearly visible. Therefore, the eight principle points of the compass are usually shown on the compass rose in black which stands out easily. Against this background, the points representing the half-winds are typically colored in blue or green and because the quarter-wind points are the smallest, they are usually colored red (Thoen, 2001, para. 4).

Global Positioning System

In modern society, the successor of the navigational compass is known as the global positioning system (GPS). Although the GPS does not necessarily use the same technology as the compass, one may argue whether or not this device would be in existence if the compass had not been invented. The GPS not only tells your direction of travel, but your position on the earth within a few hundred feet. This opened scientists to several more possibilities. For example, using this technology, they have been able to develop automotive global positioning systems that are able to provide the driver with maps and step by step directions (Cotter, 2009, p. 1).

Global positioning systems are one of the most prominent life saving devices used today. Early in the morning on June 6, 1995, the call sign of U.S. Marine Scott O’Grady was heard by
an F-16 pilot flying over head. The marine captain’s plane had been shot down when a Serbian antiaircraft missile destroyed it on impact. No one believed that the pilot had survived the explosion. Now O’Grady had been on the ground behind enemy lines for a period of four days, surviving on grass and insects, sleeping by day under camouflage netting, and moving by night. It took under four hours for a search and rescue team to find O’Grady and remove him from the warzone. The reason that it took O’Grady’s rescuers merely hours to locate him was the GPS strapped to the inside of his flight jacket (Cotter, 2009, p. 2).

The global positioning system is a major part of modern society. It saves lives, creates hundreds of thousands of jobs, and improves the lifestyle of millions of people. However, this device would never have been invented without the navigational compass. There are several aspects of the GPS that stem from the compass. For example, the compass rose is mimicked on the display screen of most GPS. This system of determining direction is unique in that there are sixty four different possible directions create using only four different words (Cotter, 2009, p. 2).

The navigational compass was one of the most important inventions in history. It sparked an enormous age of exploration which in turn brought great wealth to Europe. This wealth is what fueled later events such as the Enlightenment and the Industrial Revolution. It has been continually simplifying the lives of people around the globe since its introduction to the world. Also, it has undergone periods of deterioration and improvement throughout its lifespan. In the modern world, its successor saves the lives of soldiers, while at the same time simplifying the lifestyle of ordinary people. The world would be a truly different place without the navigational compass.

Literature Cited


Chapter 15

The Light Bulb

Introduction

In the 1950s and 1960s, the Army released bacteria in hundred of tests in areas of high population density throughout the country (Cole, 2009, p. 3). Agents dropped light bulbs containing the bacteria in the New York subway (Cole, 2009, p. 3). The bacteria used in the tests posed little risk to the welfare of the public, unlike a possible attack of a biochemical nature (Cole, 2009, p. 3). The demonstration proved that a terrorist attack potentially could expose millions of people to harmful organisms by simply using a light bulb (Cole, 2009, p. 3). In 1996, the light bulb was used again in a similar government-operated experiment (“Airports and Subways,” 2006, para. 1). The Special Operations Division of the United States dropped light bulbs filled with rare, non-pathogenic bacteria to test the vulnerability of New York to a biological attack (“Airports and Subways,” 2006, para. 1).

Weeks after dropping the light bulbs in the subways, agents tested for the presence of the bacteria in various locations across the city (“Airports and Subways,” 2006, para. 1). The use of light bulbs was an unusual but effective method for releasing bacteria. The light bulbs used today are similar to the one Edison invented in the late 19th century, and are seldom regarded as complex or important technology (“Airports and Subways,” 2006, para. 1). However, they proved to be useful in a modern and significant study regarding biological warfare and have heavily impacted industry and technology since their invention (“Airports and Subways,” 2006, para. 1).

Early Development of the Light Bulb

The first light bulb prototype, called the arc lamp, was developed by English chemist Humphrey Davey (Douglas, n.d., para. 4). The lamp produced an electric arc that emitted light as the current passed through an ionized gas (Douglas, n.d. para. 4). Davey used two strips of charcoal to produce his current, which gave off an intense light when ignited (Douglas, n.d., para. 4). Davey’s arc lamp began the search for an incandescent artificial light source in the early nineteenth century. Another English scientist who sought an incandescent light source, Warren De la Rue, invented his own light bulb in 1940 (Douglas, n.d., para. 5). De la Rue’s light bulb, with its vacuum and filament design, more closely resembled the light bulb that would be patented by Edison years later. He put a platinum filament in an airless tube and passed electrical current through it (Douglas, n.d., para. 5). The design worked, but was impractical for commercial use because of the high price of platinum (Douglas, n.d., para. 5). The search for a filament that was as durable and efficient as platinum would hinder the development of the light bulb for years (Douglas, n.d., para. 6). Other inventors turned to light bulb designs that did not involve filaments, including neon.
Neon Gas in Light Bulbs

Neon gas was first discovered in 1898, although the luminescent properties of certain elements were observed as early as 1675 by a French astronomer (Bellis, n.d., para. 1). Scientists soon discovered that if the mercury in a barometer tube were shaken, it produced light, called barometric glow (Bellis, n.d., para. 1). However, the cause, static electricity, remained unknown (Bellis, n.d., para. 1). After the discovery of the principles of electricity, scientists were able to apply this phenomenon to light bulbs (Bellis, n.d., para. 2). Around 1902, Georges Claude was the first person to develop a light bulb by charging a sealed tube containing neon gas, thereby inventing the first neon light bulb (Bellis, n.d., para. 6). His neon light was first introduced to the public in Paris in 1910 and was patented in 1915 by the United States Patent Office (Bellis, n.d., para. 6-7). The first neon gas signs were sold to a Los Angeles car dealership for $24,000 (Bellis, n.d., para. 8). The neon light bulb became popular in advertisement because it could be seen in daylight (Bellis, n.d., para. 9).

Edison, Swan, and Further Development of the Light Bulb

Thomas Alva Edison launched the United States into the electric age (Bredhoff, 2009, para. 1). With nearly no formal education, Edison engineered a number of inventions that changed the course of technology (Bredhoff, para. 1). Along with his numerous inventions, Edison also founded the first industrial research laboratory in the world (“Edison,” 2009, p. 1). Edison’s laboratory in New Jersey produced 1,093 patents (“Edison,” 2009, p. 1). However, he received the most recognition for his contribution to the invention of the modern light bulb.

In 1860, nearly twenty years before Edison’s patent, English physicist Joseph Swan developed an incandescent lamp using a filament of carbonized paper in an evacuated glass bulb (“Electric light,” 2009, para 1). Swan's design was essentially identical to Edison’s (“Electric light,” 2009, para 2). Both inventors enclosed a carbon filament in a glass bulb, removed the air, and then sealed the bulb (“Electric light,” 2009, para 2). If the bulb was not vacuum sealed, the oxygen would allow the hot filament to burn (“Electric light,” 2009, para 1). The difficulty of achieving a strong enough vacuum and a non-adequate electric source caused the light bulb to have a short lifetime and produce weak light (“Electric light,” 2009, para 1).

In 1880, after vacuum techniques had improved, both Swan and Edison produced a useful light bulb (“Electric light,” 2009, para 2). However, Edison received the most credit for the invention of the incandescent light because he also developed the power lines and other equipment necessary to integrate it into a practical lighting system (“Electric light,” 2009, para 2).

Although vacuum techniques had improved, carbon filament could not be heated enough to give off a white glow for the best lighting without rapidly deteriorating (“Electric light,” 2009, para 3). Therefore, early lamps produced a yellowish light because the carbon filament could not be raised to such an elevated temperature (“Electric light,” 2009, para 3).

However, this problem was solved in the early 20th century with the development of tungsten filaments (“Electric light,” 2009, para 4). Light bulbs containing the filaments quickly
replaced light bulbs made carbon, tantalum, and metalized carbon (“Electric light,” 2009, para 4). Because tungsten had a higher melting point than carbon, it allowed lamps to incandesce at a higher temperature and emit more light and whiter light using the same amount of electrical input (“Electric light,” 2009, para 4). However, the tungsten filament evaporated slowly at high temperatures and released particles that blackened the interior of the bulb (“Electric light,” 2009, para 5). As the filament released the particles, it thinned until it broke, causing the bulb to burn out (“Electric light,” 2009, para 5). The thinning effect was reduced in the gas-filled lamps that were introduced in 1913 (“Electric light,” 2009, para 5). These lamps were filled with argon or nitrogen that exerted pressure on the filament, preventing its evaporation and allowing it to run at a higher temperature, producing a brighter light, and giving the bulb a greater efficiency and a longer life (“Electric light,” 2009, para 5).

In 1959, the halogen lamp was introduced (“Electric light,” 2009, para 6). It lasted longer than the other incandescent lamps available (“Electric light,” 2009, para 6). The halogen bulb used the tungsten filament like other bulbs, but was filled with gases from the halogen family (“Electric light,” 2009, para 7). The halogen prevented particles from depositing on the interior walls of the bulb, keeping it cleaner and allowing the bulb to last longer (“Electric light,” 2009, para 7). Also, the halogen gas increasing the melting point of the filament contained within and allowed the bulbs to operate at exceptionally high temperatures (“Electric light,” 2009, para 7).

For decades before the first light bulb was invented, scientists had failed to produce a practical long-burning electric light (Bredhoff, 2001, para. 3). Edison gained financial backing and assembled a group of scientists and technicians in an attempt to develop an effective and affordable electric lamp (Bredhoff, 2001, para. 3). Edison had unwavering determination and, along with his team, tried thousands of theories (Bredhoff, 2001, para. 3). Edison wanted to connect his lights in a parallel circuit by subdividing the current, unlike arc lights which were connected in a series circuit (“Edison,” 2009, p. 5). A parallel circuit would prevent the failure of the whole circuit if one light bulb failed (“Edison,” 2009, p. 5). Some scientists believed that such a circuit was not feasible (“Edison,” 2009, p. 5). However, the findings of these scientists were purely based on systems of lamps with low resistance—the only efficient type of electric light at the time (“Edison,” 2009, p. 5). On January 27, 1880, Edison received his patent which stated the principles of his incandescent lamp and laid the groundwork for the use of electric light in domestic settings (Bredhoff, 2001, para. 3). However, Edison’s many light bulb designs all contained flaws and had to be altered for greater convenience in everyday use.

The first incandescent light bulbs, invented by Thomas Edison and Joseph Wilson Swan in 1879, used carbon filaments (Douglas, n.d., para. 6). However, these light bulbs were extremely inefficient, and the filament lasted at most fourteen hours (Douglas, n.d., para. 6). After Edison’s design was patented, he began searching for more durable, longer lasting filaments (Douglas, n.d., para. 7). He used a carbonized bamboo filament that was able to last more than 1200 hours (Douglas, n.d., para. 7). The invention of ductile tungsten, which unlike regular tungsten could be drawn into wires, allowed inventors to manufacture a filament and later, in 1906, light bulbs with filaments made of tungsten (Douglas, n.d., para. 8). This light bulb is essentially the same as light bulbs we use today (Douglas, n.d., para. 8).
Light Bulb Structure

Light bulbs have a simple structure (Harris, n.d., para. 9). There are two metal contacts at the base which connect to two stiff wires and the end of an electrical circuit (Harris, n.d., para. 9). The wires attach to a thin metal filament that is held up in the middle of the bulb by a glass mount (Harris, n.d., para. 9). Modern light bulbs have filament made of a long, thin length of tungsten (Harris, n.d., para. 13). The tungsten filament in a typical sixty-watt light bulb is about 6.5 feet long but only one-hundredth of an inch thick (Harris, n.d., para. 13). The tungsten is formed into a double coil approximately once-inch long in a modern sixty-watt light bulb (Harris, n.d., para. 13). All of these elements are contained within a glass bulb filled with an inert gas (Harris, n.d., para. 9). When the bulb is attached to a power supply, an electric current flows from one metal contact through the wires and the filament to another metal contact (Harris, n.d., para. 10).

Science of the Light Bulb

Light is a form of energy that is released by an atom in the form of photons, which are packets of light energy (Harris, n.d., para. 2). Photons are particle-like units of energy that have momentum, but no mass (Harris, n.d., para. 4). The electrons of an atom have different energy levels and electrons with different energy levels reside in different orbitals (Harris, n.d., para. 5). In order for an atom to release light photons, the atom must gain energy and excite the electrons causing the electrons to temporarily relocate to an orbital farther away from the nucleus (Harris, n.d., para. 5). The electron only remains in this orbital for a fraction of a second and then returns back toward the orbital in which it was previously located (Harris, n.d., para. 5). As the electron returns to the orbital, it releases energy in the form of a photon, sometimes light photons (Harris, n.d., para. 5). The wavelength of the emitted light, which determines the color of the light, is dependent upon the type of atom excited and the amount of energy released (Harris, n.d., para. 6). The main difference between the different sources of light is process used to excite the atoms (Harris, n.d., para. 6).

Impact of the Light Bulb on History

The invention and development of the light bulb has had a profound impact on history. The impact was first noticed when networks of wires used to power the first electric lights were erected across the country (Douglas, n.d., para. 9). The light bulb had essentially prompted domestic electrical wiring (Douglas, n.d., para. 9). Edison built the first of his power generating plants with distribution systems in Manhattan in 1882 (Eby, 2009, para. 16). In the years subsequent to urban electrification, private utility companies felt they could make larger profits in cities because there would be no need for a lengthy distribution system (Eby, 2009, para. 27). They believed there was no market in rural areas because farmers would not utilize power (Eby, 2009, para. 27). There was a long, hard fought battle to receive rural electrification. In 1935, nearly fifty-three years after Edison invented the light bulb, President Franklin D. Roosevelt issued the order to form the Rural Electrification Administration (REA) (Eby, 2009, para. 17). The REA was an independent relief agency that loaned money to rural electric co-ops, states, and territories (Eby, 2009, para. 48). States were assisted by the REA based on their need of
electricity; states like Georgia that were barely electrified would receive more loans than California where more than half of the population was receiving power (Eby, 2009, para. 49). The administration ensured that all farmers had equal access to electricity in their area, no matter how poor or wealthy they were (Eby, 2009, para. 50). In 1936, nearly ten percent of all farms had electricity thanks to the REA (Eby, 2009, para. 15).

The networks were also precursors to the numerous advancements in commercial electrical appliances (Douglas, n.d., para. 9). The convenience of easily accessible light and the electricity that powers the lights and other appliances in the home are central to daily life and cannot be underestimated (Douglas, n.d., para. 3). The popularity of standard incandescent bulbs can be attributed to their inexpensiveness and ease in use (“Electric light,” 2009, para 8).

However, both standard and halogen incandescent bulbs have disadvantages (“Electric light,” 2009, para 8). The bulbs expend most of the energy they produce as heat, only approximately five to ten percent of the energy consumed by the bulb is converted to light (“Electric light,” 2009, para 8). The light bulb heavily impacted the world on a global scale (Douglas, n.d., para. 3).

**Recent Developments and Future Extensions of the Light Bulb**

Modern day light bulbs have the same general format as the ones developed by Edison and Swan nearly 130 years ago (Pullen, 2007, para. 1). However, the older bulbs are inefficient, only converting approximately five percent of the energy they consume into light (Pullen, 2007, para. 1). Modern “energy efficient” light bulbs get rid of are known as CFLs, or Compact Fluorescent lamps, consume seventy-five percent less energy and last ten times longer than older light bulbs (Pullen, 2007, para. 2). These bulbs can reduce a homeowner’s electric bill by thirty to seventy percent (Pullen, 2007, para. 2). These bulbs come in many different designs, wattages, and sizes (Pullen, 2007, para. 2). Therefore, energy efficient bulbs are nearly as available to the consumer as older, non-efficient bulbs.

Luxim, a company located in Silicon Valley, California, developed a light bulb that emits as much light as a streetlight while confined in a chamber the size of a Tic-Tac (The Lightbulb of the Future?, 2008). The gas in the bulb is argon. The bulb works by having electrical energy transferred to a component called a puck which acts like a lens, focusing all the energy to a defined area (The Lightbulb of the Future?, 2008). The chamber is filled with argon gases that increase in temperature, change into plasma, and emit light (The Lightbulb of the Future?, 2008). Compared to older light bulbs, a considerable amount of the energy consumed by the bulbs is converted into light rather than heat (The Lightbulb of the Future?, 2008). An ordinary light bulb gets approximately 15 lumens per watt; however, the light bulbs produced by Luxim get approximately 140 (The Lightbulb of the Future?, 2008). The advantage of the Luxim bulbs is that the bulb is energized without any electrodes. In the chamber of the bulb, the plasma reaches the same temperature as the surface of the sun (The Lightbulb of the Future?, 2008).


