

2015

Technology and its Effect on Healthcare

Sarah Manis
Grand Valley State University

Follow this and additional works at: <https://scholarworks.gvsu.edu/honorsprojects>



Part of the [Medicine and Health Sciences Commons](#)

ScholarWorks Citation

Manis, Sarah, "Technology and its Effect on Healthcare" (2015). *Honors Projects*. 382.
<https://scholarworks.gvsu.edu/honorsprojects/382>

This Open Access is brought to you for free and open access by the Undergraduate Research and Creative Practice at ScholarWorks@GVSU. It has been accepted for inclusion in Honors Projects by an authorized administrator of ScholarWorks@GVSU. For more information, please contact scholarworks@gvsu.edu.

Technology and its Effect on Healthcare

Honors Senior Project | Winter 2015 | HNR 499

Sarah Manis

Technology has quickly become an integral part of society over the last century. Most of what is now considered common technology has not always been so easily available to the general public. With every improvement in the world of technology that seems small, huge advancements can arise. Many of these trivial improvements have monumentally impacted society as a whole. The evolution of technology as a whole has laid the groundwork for countless industrial advancements that have improved the inner and outer workings of today's world. More specifically, these advances have developed and transformed the ever-expanding realm of healthcare. While the implementation of technology has improved many aspects of healthcare, it is also possible for the application of these technologies to have negative implications as well. As society strives to continuously improve, the medical field stops at nothing to provide the highest quality of healthcare possible. Finding and appreciating the balance of when technology may bring about more harm than good will dramatically change and improve healthcare as a whole. While healthcare in its entirety encompasses too many different disciplines to adequately and thoroughly investigate the effect that technology has had, this paper will investigate and consider just a few of these countless technological advances within the medical field. These advances will include the completion of the Human Genome Project and the scientific healthcare advances that have accompanied it.

The Human Genome Project is an extensive example of technology use in the medical field. Without technology and the ambitions to constantly improve upon it, this project would have never been successful. Overall, the Human Genome Project

was designed to decipher and interpret the entire sequence of the human genome in order to use it as a reference for future discoveries. After decoding this reference human genome sequence, this project led to the development of innovative technologies and tools to be used in countless ways. Not only has it helped in the realm of healthcare, but beyond medicine as well. In addition to changing the world of medicine, the Human Genome Project has revolutionized the disciplines of microbiology, virology, infectious disease and plant biology. (Hood) However, for the purpose of this paper, the investigation of the Human Genome Project will stay within the boundaries of healthcare and medicine.

Since the decoding of the reference human genome, individual genome sequences are starting to play a more important role in medicine and healthcare. In today's society, and more so in the future, patients will have the ability to customize their own healthcare based on their individual genome. Doctors will be able to recommend more preventative medicine if they interpret a genome and see the potential for the development of minor or more serious diseases. In addition to individualizing preventative medicine, doctors can individualize therapeutic programs to prevent or treat current or potential conditions suggested by their individual genome sequence. (Hood) Currently, the process to sequence the human genome is not being used routinely in everyday medicine, however, the sequencing of the human genome only costs \$100 or less and can take 15 minutes or less. Once the process of sequencing the human genome has become more widely accepted, it will make diagnosis and treatment easier and more individualized, improving the healthcare provided to each patient.

As genetic testing is becoming more and more accessible, it is also becoming easier to personalize healthcare. Even before genetic testing was possible, diagnosis included the consideration of environmental influences and also the familial history of disease. (Blix) A family history can be an important tool that doctors use to diagnose an individual. If a patient is having certain symptoms and the doctor knows that the symptoms align with a disease that runs in their family, that information can help to confirm a diagnosis. However, with more advanced technologies, doctors will be able to use the patient's genome to help diagnose the individual instead of relying on the familial history given by the patient. Often times, the history given by the patient has many gaps and at times can contain incorrect information. Now that research has revealed more about genetics and genomics, these discoveries have helped in the fields of medicine and pharmacology, affecting risk assessment, diagnosis, prognosis, and treatment. (Blix) Especially in cancer situations, genetic assessment can be used to find the potential for familial risk based on an individual's genome. In the area of diagnosis, genomics is also becoming more popular in order to differentiate different subtypes of cancers. This is an important step forward when it comes to the diagnosis and treatment of each individual cancer. This has even led to the beginning of the Cancer Genome Atlas project. The ability to genome a cancer cell has also become important when it comes to determining the severity of disease the prognosis. (Blix) Understanding the progression of the disease and prognosis for the patient is important information for the patient when it comes to making important decisions about their well-being and future.

Researchers are continuing to use the information provided by the Human Genome Project to improve healthcare. In the field of pharmacogenomics, researchers have found more than 70 genes that have specific variants that can cause ineffective drug metabolism in humans. (Hood) Pharmacogenetics is a field of research that helps to understand how an individual's genetics can display their inter-individual variability in response to different drugs. Pharmacogeneticists study individual genomes to identify inherited genetic differences in drug metabolic pathways, which can influence an individual's response to various medications. In medical terms, this can mean metabolizing a drug too quickly and therefore decreasing the length of benefit, or too slowly causing an increase concern for toxicity. Altered drug metabolic pathways can also affect the drugs therapeutic effect and the adverse effects of the drug. The term pharmacogenetics is used to describe a single variation, or a polymorphism, in the genome and how it can affect drug response. (Birdwell) The majority of drugs display this type of inter-individual variation in their effectiveness. One of the most important applications of pharmacogenetics is simply to avoid some of the more serious and life threatening adverse reactions a drug can induce.

Approving new drugs involves many different steps and the success of the drug is based on its effectiveness. Generally, their efficacy is based on the average response of the group used in the study. However, this average implies there are still individuals with little to no response and other individuals with too powerful of a response. These individuals with little to no response or an above average response are such a small percentage of the total number of individuals in the group that their

responses don't affect the overall efficacy of the drug. When treating more complex diseases, these patients often go through 'trial-and-error' periods until a sufficiently successful therapy has been found. (Liggett) This trial-and-error period includes changing the dosage and frequency of drug administration, or changing the drug itself to a different drug with the same benefit. This can often be a frustrating and time consuming strategy to find the proper treatment. It is also important to consider that during this trial period, the patient may not be experiencing any relief because the dosage, frequency, or drug may not be administered optimally. Using the information that the genome provides, patients with an altered pattern of drug metabolism can be given different doses or frequencies without the hassle of a long trial-and-error period. Drugs can also be chemically modified in order to accommodate this altered pattern of drug metabolism.

In addition to identifying individuals with unique drug metabolisms, genetic testing can help to determine whether an individual is likely to experience side effects when taking a certain drug. Each individual will react to a drug differently. Oftentimes it does not cause harmful results, but there are times where the reaction to the drug is worse than the problem the drug was originally treating. The ability to foresee the occurrence of any side effects can help doctors suggest strategies to reduce or eliminate them and improve the health and livelihood of the individual. This application of pharmacogenetics allows doctors to choose the best drug out of all the available options, choose the correct dose and frequency right away, and save time and money by not having the trial-and-error period. These are benefits that can be very important when it comes to the overall wellbeing and care of the patient.

The Human Genome Project has also identified hundreds of 'actionable gene variants.' (Hood) These actionable gene variants are variations of various genes that have the potential to cause disease. Sequencing an individual's genome and identifying these specific actionable gene variants can indicate the need for medical intervention in order to avoid experiencing the effects of the disease. The sequencing of individual genomes can also help to identify various mutations that cause cancer. Once a cancer causing mutation occurs, it is important to start treatment as soon as possible after it has been identified. Once the mutation causing the cancer has been identified, doctors can use treatments and medications that are already on the market in order to try to treat and counteract the mutation. (Hood) This can include using a specific drug that is well-known to treat a certain mutation. It can also include formulating a new and personalized cocktail of several drugs that are already on the market to try to combat the mutation. With a disease like cancer, many treatments need to be highly individualized because different mutations require different treatments. Given the nature of mutations and cancer, using drugs that are already on the market is much more timely and can be much more effective. The development and approval of new drugs to treat new mutations is very costly and can take several years. It is costly for both the pharmaceutical company and the patient because new drugs under patents are considerably more expensive because the company must make back the money they lost during the development of the drug. Even so, with these important considerations aside, when a new drug is finally approved, it is possible that the mutation the drug was developed to counteract has changed and mutated again and the drug will not be as effective as expected. With

the sequencing of cancer genes, drugs that are already on the market can be tailored and used in individuals to fight certain types of cancer mutations.

The Human Genome Project was the first example of a 'large-scale data acquisition.' It was an extensive group project. The project itself required the cooperation of engineers, computer scientists, mathematicians, and biologists in order to create data sharing and specific software to interpret the information and to make the results of the project obtainable by everyone. The technological advancements made to accomplish the Human Genome Project started to revolutionize the realm of science and more specifically medicine. Not only did the Human Genome Project suggest new ways to prevent and treat disease in the future, it also inspired future large-scale data acquisitions such as: the International HapMap Project, 1000 Genomes, the Cancer Genome Atlas, the Human Brain Project and the Human Proteome Project. (Hood) Each of these projects will continue to influence the medical field and allow for dynamic and exceptional healthcare.

From the creation of the Human Genome Project, many companies have taken on this idea to improve their own research. A company called 23andMe is a well-known company striving to help people access, understand and benefit from the human genome. The idea behind this company is so individuals can order a DNA testing kit, follow the instructions and send it back to the company. The company will then interpret the DNA from the kit and send the results back to the individual. A unique characteristic of this company is if the individual chooses to participate, they can also give the company permission to use their DNA in research to help learn more about various diseases. The individual simply checks a box on the

pamphlet from the testing kit and once the company has interpreted the DNA, they send the results to the individual and then use the results for their own research. Participation in this research could potentially help with disease prevention, improved drug therapies, disease treatments and genetic paths to cures. It can also provide information about how various diseases are passed down through generations. However, not only can these DNA tests help to discover treatments and cures for the future, it can also be used to study ancestry, connecting people all around the world. This company is one of many that are trying to make genetic testing more common and effortless in order to help individuals learn more about themselves and their own healthcare.

While the Human Genome Project has revolutionized modern science and modern medicine, it has also introduced a new ethical consideration that wasn't possible until now. Having the ability to sequence the genome could provide the doctor with life-changing information for the patient. A general example of this would include finding possible causes of death of an individual based on their genome. One significant example would be in the case Alzheimer's Disease. Although the cause of late-onset Alzheimer's Disease is unknown and is suggested to be related to both genetics and environmental factors, the inheritance pattern of early-onset Alzheimer's Disease is autosomal dominant. This means that an individual only needs one copy of the gene, instead of two, in order to develop Alzheimer's disease. Since early-onset Alzheimer's Disease typically presents itself in the ages of 30s, 40s, and 50s, an individual with the dominant gene has most likely already reproduced and passed their genes onto their offspring without knowing. The

chance that any one of their offspring will inherit the gene for early-onset Alzheimer's Disease is 50%. With the ability to sequence the human genome, individuals whose parents have developed early-onset Alzheimer's Disease can have their genome sequenced to see if their genome also contains an inherited autosomal dominant gene linked to Alzheimer's Disease. This brings many ethical considerations to light. Although there are several more ideas to consider, the two main considerations involve the decisions the individuals makes about their future. Before knowing whether or not a person has the gene for early-onset Alzheimer's Disease they may have dreams to get married and start a family. However, if an individual carries the gene, they may choose not to start a family in order to prevent passing the gene on to the next generation. However, to counteract this perspective, the individual may not live the life they dreamed and may live with fear and anxiety of what will happen to them in the future. This fear and anxiety may also lead to other illnesses and disease states, diminishing their overall health. While the Human Genome Project has helped to improve healthcare tremendously, it is important to gain an appreciation for the technology available, but also to understand how to create a balance when it comes to technology use in the world of healthcare. Just because the technology allows individuals to gather this information about themselves, doesn't mean it should be done.

Downs Syndrome is another example of how technology has brought about various ethical dilemmas. Downs Syndrome is the trisomy of chromosome 21. As humans, we function optimally with two of each chromosome. Any type of variation from this norm causes abnormalities. Although the individual will live with

abnormalities, there are three types of chromosomes that when in trisomy the human can survive. Chromosomes 13, 18, and 21 are the only trisomies that make it to birth, and even then many of them do not make it to birth. All other chromosomal trisomies will naturally abort, often before a pregnancy is diagnosed. Before birth, during gestation, a mother can choose to find out whether or not the child has Down's Syndrome. Based on the outcome of these tests the mother can choose to abort the pregnancy and there are times when this option is even recommended by the physician. Although the child can still live a happy life with Down's Syndrome, the mother has the ability to end the pregnancy if she does not want to have a child with Down's Syndrome. This ethical dilemma illustrates some of the difficult decisions that come along with the use of technology in healthcare.

In addition to the examples of Alzheimer's Disease and Down's Syndrome, genetic testing and genetic counseling have been shown to be beneficial in the case of cancer. As specified earlier, genetic testing of the disease itself can help doctors choose the proper treatment in order to offer the most promising prognosis for the patient. However, in the case of family history, an individual can find out if they carry the genes that could become cancer. If an individual carries the gene that doesn't mean that they will get cancer, but it drastically increases their likelihood of developing cancer. This use of genetic testing is often used as a preventative measure. In the case of breast cancer, if an individual is likely to develop the disease, there are many preventative options. They can choose to have a double mastectomy before the disease has progressed at all, preventing the cancer from starting in the first place. If the organ that the cancer targets is removed before the cancer

develops then the cancer can no longer develop in that organ. This situation is different from that of early onset Alzheimer's Disease because Alzheimer's Disease cannot be prevented as of now. Choosing to have genetic testing done in order to undergo preventative surgery or treatment for a disease like cancer does not bring about the same ethical dilemmas and decisions that genetic testing for Alzheimer's Disease suggests.

The Human Genome Project was just the beginning of many genome projects to come, all influencing the medical field in different ways. Another specific project that is still in the workings is the Human Microbiome Project. The human microbiome includes the microbial on the surface of and within the human body. The idea of this project came after the Human Genome Project because there was a growing interest in sequencing the genomes of the microbial life in and on the human body. (Gevers) Researchers understood that the microbiome was necessary and beneficial to human health but they had no understanding of the specifics of the microbial matter. After significant research, it was discovered that the gastrointestinal tract harbors the most prolific and one of the most diverse microbial communities of the entire human body. (Manichanh) The human body is comprised of two genomes, one is inherited through our genetic lineage, and the other is acquired. (D'Argenio) Unlike the typically stable inherited genome, the acquired genome is dynamic and can be influenced by a number of factors. (D'Argenio) This acquired genome includes the genetic diversity of microorganisms living on the surface of and within the body itself. Together, with hundreds more, these microorganisms contribute to the health of every human being. Due to the

lymphoid tissues present within the mucosa and the magnitude and complexity of the microorganisms within it, the gut microbiome is important for maintain the homeostasis of individuals. (Manichanh)

There are various events that can influence the microorganisms within the human gut. With the help of the Human Microbiome Project many discoveries have been found that can be used to help individuals make better decisions regarding their health and the health of those around them. Researchers have discovered that the development of the gut microbiota begins during the birthing process. Before this moment, an infant is sterile. (D'Argenio) During vaginal delivery, the infant comes into contact with the mothers' vaginal and intestinal flora. This is an important source for microorganisms that will begin to colonize in the gut of the infant. This source of microorganisms is so important because it contains many of the types of microorganisms within the gastrointestinal tract of the mother. The predominant species acquired from a vaginal birth include lactobacillus, prevotella, and other bifidobacterium. (Torrazza) Unlike during vaginal delivery, the infant is not exposed to the same flora during a cesarean delivery. During a cesarean delivery, direct contact of the mouth of the infant with the vaginal and intestinal flora is absent. (Torrazza) The infants delivered by cesarean are exposed to non-maternally derived and less diverse flora dominated by staphylococcus with delayed intestinal colonization by lactobacillus, bifidobacterium and bacteroides. (Torrazza) Depending on if a child is delivered vaginally or via cesarean birth, the individual may have a drastically different microbial composition and acquired genome and therefore the metabolism, nutrition, immunological functions and pathogen defense

can be different. This can have lasting effects on the individual as it develops. There have been links found in infants delivered by cesarean showing that they display diseases such as Asthma, type 1 diabetes, allergies, celiac disease, irritable bowel disease and obesity more often than infants delivered vaginally. (Torrazza)

In addition to the mode of delivery and its influence on the development of the microbiome, individuals on antibiotics have an altered gut microbiota. This is commonly found in the medical field. Antibiotics are some of the most commonly prescribed drugs in the United States and each antibiotic comes with its own adverse side effects. Often times, antibiotics can lead to stomach and intestinal upset. This is due to the change in microbial diversity within the gut. Antibiotics are unable to decipher between good and bad bacteria. Antibiotics are used to get rid of bacteria within the body that are causing illness, but in doing so, antibiotics can also destroy some of the good bacteria within the gut, leading to a disequilibrium and unfortunate adverse reactions. These adverse reactions can include stomach upset, loose or watery bowel, and diarrhea. Due to these adverse reactions, there have been suggested ways to reestablish the microbial diversity within the gut in order to avoid some of these adverse side effects before they begin. The use of probiotics is a relatively new topic in research. Since antibiotics alter the intestinal flora, it can lead to symptoms such as large watery bowel movements and cramping abdominal pain. One small study concentrated on antibiotic-associated diarrhea focused on the use of *Lactobacillus reuteri*, which was found to decrease the frequency of diarrhea in patients receiving antibiotics within hospital setting. (Balakrishnan)

Another disease that is gaining attention in the medical field is *C. difficile*. This is one of the most commonly seen nosocomial infections in both the hospital and nursing home settings. (Balakrishnan) *C. difficile* is a microbe that is always present in the gut microbiota, however, not in concentrations that cause harm. The use of antibiotics can alter the gut microbiota allowing the *C. difficile* to germinate and grow and increase in concentration within the gut. This common and growing problem has helped in the development of more ways to reestablish an altered gut microbiota. In addition to probiotics, another way to reestablish the microbial equilibrium is through fecal microbiota transplants. Fecal microbiota transplantation is the process of delivering a saline stool suspension from a healthy, preapproved donor into the patient's upper gastrointestinal tract. (Lofland) It works to restore the microbial homeostasis within the intestinal environment in order to relieve the diarrhea and colitis that is associated with an overgrowth of *C. difficile* by increasing the population of good bacteria. (Lofland) With the help of further research, more information about the varying genomes in the gut will help to learn more about probiotics, fecal microbiota transplantation and other treatments will be revealed and integrated into the medical care of individuals suffering from an altered gut microbiota.

Once the human genome project was completed, the technology that was used has continued to help the medical field in many different ways. With the human microbiome project, there is still much more research to do, but so much has already been found and has helped many individuals. With the knowledge of how the birthing process can change the microbial diversity of an individual, healthcare

workers can help individuals make more educated decisions about their lives and the lives of their children. Also, the knowledge of how to re-establish a low microbial diversity gut has been very beneficial in the medical field and improving the lives of many individuals.

Overall, technology has had a profound impact on the healthcare community. Although this paper only covers a small percentage of the impact, it is easy to say that technology has revolutionized modern medicine and diagnostics. While there are so many obvious aspects of technology that have been beneficial and extremely significant in improving the healthcare that is provided, many of the unfavorable effects have been overlooked. These unfavorable effects include the ethical situations that come up when technology allows individuals to gain access to specific personal information they would not have been able to obtain had technology not intervened. Ultimately, this purpose of this paper is to provoke thoughts and reflection on how technology has permeated the healthcare system. As each individual has the ability to make their own decisions in regards to their health, it is important to learn to appreciate the role that technology should have in such a personal aspect of life but also to set boundaries where technology should not penetrate.

References

- Balakrishnan, M., & Floch, M. (2012). Prebiotics, probiotics and digestive health. *Current Opinion in Clinical Nutrition and Metabolic Care*, 15(6), 580-585. Retrieved January 15, 2015.
- Birdwell, K. (n.d.). Role of pharmacogenomics in dialysis and transplantation. *Current Opinion in Nephrology and Hypertension*, 1-8. Retrieved March 11, 2015.
- Blix, A. (2013). Personalized Medicine, Genomics, and Pharmacogenomics: A Primer for Nurses. *Clinical Journal of Oncology Nursing*, 18(4), 437-441. Retrieved February 21, 2015.
- D'Argenio, V. (2014). The role of the gut microbiome in the healthy adult status. *Clinica Chimica Acta*, 1-6.
- Gevers, D., Knight, R., Petrosino, J., Huang, K., McGuire, A., Birren, B., . . . Huttenhower, C. (2012). The Human Microbiome Project: A Community Resource for the Healthy Human Microbiome. *PLoS Biology*, 10(8), 1-5. Retrieved February 21, 2015.
- Hood, L., & Rowen, L. (n.d.). The human genome project: Big science transforms biology and medicine. *Genome Medicine*, 5(79), 1-8. Retrieved March 11, 2015.
- Liggett, S. (March 2001). Pharmacogenetic applications of the Human Genome project. *Nature Medicine*, 7(3), 281-284. Retrieved March 11, 2015.
- Lofland, D. (2013). Fecal Transplant for Recurrent *Clostridium difficile* Infection. *Clinical Laboratory Science*, 26(3), 131-135.

- Manichanh, C., Reeder, J., Gibert, P., Varela, E., Llopis, M., Antolin, M., ... Guarner, F. (2010). Reshaping The Gut Microbiome With Bacterial Transplantation And Antibiotic Intake. *Genome Research*, 1411-1419. Retrieved January 16, 2015.
- Torrazza, R., & Neu, J. (2011). The developing intestinal microbiome and its relationship to health and disease in the neonate. *Journal of Perinatology*, S29-S34. Retrieved January 20, 2015.