Sociotechnical Imaginaries Developed by Biotechnology Companies through CNT-based and lipid-nanoparticle-based mRNA vaccines

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

Since the COVID-19 pandemic, there have been many advances in the realm of vaccine development. From new delivery methods to newly discovered targets for rare diseases, vaccines have transformed the ability of physicians to treat infectious diseases. Currently, there are 96 FDA-approved vaccines for various infectious diseases (U.S. Food and Drug Administration, 2023). Many of these vaccines lead to the innovation of new technology such as delivery systems to make them more effective. However, the introduction of new technology in this field has led to questions about the social, political, ethical, and economic implications of vaccines.

COVID-19 raised issues about vaccine hesitancy and distribution equality. This was fueled by adverse side effects and lack of trust from patients in the expedited approval process for the COVID-19 vaccines. The percentage of people that accepted COVID-19 decreased from 89% to 72% between August 2020 and June 2021 (Joachim et al., 2024). This presents a challenge for biotechnology companies that are developing new technology for vaccines. It is important for these companies to understand the issues of vaccine hesitancy and distribution equality and address them as they develop new technology. By addressing these issues, biotechnology companies can help increase public health as more people become vaccinated.

The traditional method of vaccine development utilizes live-attenuated vaccines or inactivated vaccines. Live attenuated vaccines are live viruses that are weakened to expose the body's immune system to the virus. The body builds a system to fight this virus and recognize it in the future. However, these vaccines have drawbacks. The main concern is contracting the illness from the vaccine. While it is weakened, the virus still has the ability to infect a host (Wodi & Morelli, 2021). For certain diseases such as HIV-1, this can have large implications because it is life-long and treatment methods are costly. Inactivated vaccines are dead viruses that can be recognized by the body. Similar to the live, attenuated vaccines, the body enact a response to this virus and recognize it in future infections. However, inactivated vaccines do not elicit strong immune responses and can require multiple dosages for effective protection (Wodi & Morelli, 2021).

To combat the issues around traditional methods, biotechnology companies have become interested in mRNA vaccines especially with the COVID-19 vaccines. Messenger RNA is genetic code that is produced by the body as a template for proteins. In a vaccine, mRNA encodes for a protein of interest that can be recognized by the immune system. In a way, mRNA vaccines mimic the virus without containing elements of infection (Barbier et al., 2022). Therefore, mRNA vaccines reduce the risk of infection. Additionally, it can elicit a strong response in the body and therefore, increase the chances of protection against infection. However, mRNA degrades quickly in the body and therefore needs an effective delivery system to transport it through the body (Xu et al., 2023). The COVID-19 vaccines utilized a liposome-based vaccine delivery system. Lipid nanoparticles are micelles of fats that form through hydrophobic interactions and trap the mRNA (Schoenmaker et al., 2021). Another delivery method of interest is carbon nanotube-based vaccines. Carbon nanotubes (CNTs) are tubes of carbon networks that can be used as a scaffold to hold proteins or mRNA (Xu et al., 2023). Together, with mRNA, liposome-based and CNT-based vaccines promise positive implications for the effectiveness of vaccines and prevention of disease.

In this paper, I argue that biotechnology companies present sociotechnical imaginaries of social equality, public safety, and economic development through CNT-based and liposome-based vaccines. The biotechnology companies I analyze are Luna Labs and Pfizer because of their research in CNT-based vaccines and lipid nanoparticle vaccines. They have published research in these vaccines and discuss their hopes for the vaccines on their websites. Luna Laboratories is a small technology firm in Charlottesville that has a biotechnology department through which they are developing a carbon-nanotube-based vaccine platform (NanoVac) for HIV-1. In my literature review, I discuss the vaccine distribution issue, vaccine hesitancy issue, and the benefits of mRNA vaccines as a method of addressing these issues. I collected primary and secondary sources that highlight the motivations of biotechnology companies. These sources include the company websites, published research by these companies, and secondary literature reviews about these issues. I analyzed them using the sociotechnical imaginaries framework that seeks to understand the role of technology in creating a socially desirable future envisioned by the companies. I found that biotechnology companies use empowering language to portray their vaccines as tools to create the imaginaries for a desirable future. I conclude with a discussion on how these sociotechnical imaginaries can be used to encourage the development of technology in response to social issues and the future about the potential hindrances to achieving these imaginaries.

Literature Review:

While biotechnology companies that make vaccines promise to eliminate disease in the world, there are problems that can prevent this goal. In particular, vaccine inaccessibility allows for the unequal distribution of vaccines in communities. According to Hill et al. (2016), the main hindrances to vaccine accessibility are inadequate healthcare resources, vaccine coherence after a long storage period, and lack of adequate manufacturing capacities. In rural and low income communities, the lack of funding and healthcare workers results in less effective distribution of vaccines and therefore affects the efficacy of the vaccine in preventing disease (Hill et al., 2016). This partly is due to the instability of vaccines over a long period of time. Vaccines are distributed through a cold chain system which “can account for up to 80% of vaccination costs” (Hill et al., 2016, p. 69). Vaccines are required to be stored and delivered in refrigerated spaces to ensure their stability. However, rural and low-income communities often do not have the refrigeration infrastructure and funding to store these vaccines for long periods of time. This leads to vaccine instability and calls into question the quality of the vaccines. Additionally, vaccines cost millions of dollars to produce. From research and development to manufacturing at large quantities, vaccine production incurs large expenses which makes it difficult for companies to price vaccines at a low cost. For low-income communities, these costs can affect acquisitions of these products and therefore affect the distribution of vaccines unequally across communities (Hill et al., 2016). The World Health Organization acknowledges that a reason for inequitable vaccine accessibility is that many national healthcare systems are not capable of supporting the intricate support needed for vaccines. (World Health Organization, n.d.).

Another problem that can prevent the goal of vaccines is vaccine hesitancy. For vaccines to maximize their effect, a majority of people need to take the vaccine. This is because if majority of the people are vaccinated, the chance of transmission is lowered which therefore lowers the number of new cases of the disease. Vaccine hesitancy has become a problem that impacts the efficacy of vaccines to decrease the risk of epidemics and wide outbreaks of diseases. Some of the main concerns centering vaccine hesitancy include “lack of vaccine safety”, “lack of trust”, “lack of need of vaccination”, and “cultural reasons” (Kumar et al., 2022, p. 1518). Vaccine hesitancy has been a problem for many decades, but the COVID-19 pandemic exacerbated this issue and brought to light many of the underlying reasons for vaccine hesitancy that are mentioned above. Additionally, media scares, bad past experiences with vaccination services, and negative perception about the role of vaccines in health all increased vaccine hesitancy (Dubé et al., 2013). The boom of the internet presented the opportunity for anti-vaccination activists to share their ideas. They mostly focus on the safety of vaccines and share false narratives that support their stance. This instills fear in the public about vaccines. Negative past experiences with vaccination services such as pressurizing for vaccination has deterred parents from vaccinating their children (Dubé et al., 2013). Finally, studies have shown that parents will not vaccinate their children because they do not perceive the vaccine to be important for health. In fact, they state that "children receive too many vaccines and that vaccines can interfere with natural development" (Dubé et al., 2013, p. 1768).

In recent years, researchers have responded to these concerns and increased the effectiveness of vaccines. Messenger ribonucleic acid (mRNA) vaccines have several benefits that show promise in improving vaccines. mRNA vaccines are produced faster than other vaccines which address manufacturing challenges (Jackson et al., 2020). mRNA vaccines also can target multiple targets in the body which can increase their effectiveness (Jackson et al., 2020). Additionally, mRNA vaccines allow for stronger immune responses, reduce the risk of possible infection, increase stability, and allow for the ability to modulate its immunogenicity (Pardi et al., 2018). The first mRNA vaccines are the Pfizer/BioNTech and Moderna COVID-19 vaccines in 2020. They showcased the potential of mRNA for preventative and therapeutic applications and demonstrated that mRNA vaccines could increase manufacturing efficiency. However, mRNA is unstable in the body and therefore needs to be stabilized by adjuvants such as lipid nanoparticles such as those used in the COVID-19 vaccine (Jackson et al., 2020).

Conceptual Framework:

The framework I use to analyze the research question is sociotechnical imaginaries proposed by Sheila Jasanoff. Sociotechnical imaginaries relies on creating a desirable future through collectively held ideas about the role of technology. "The success of new sociotechnical imaginaries relies on their fit with existing cultural norms and moral values, social structures and material infrastructures, political institutions and economic systems, and hopes and aspirations" (Sadowski & Bendor, 2019, p. 544). These imaginaries play a role in how and why technology is made. Jasanoff defines co-production as an important aspect of sociotechnical imaginaries. She states that "co-production is shorthand for the proposition that the ways in which we know and represent the world (both nature and society) are inseparable from the ways in which we choose to live in it" (Jasanoff, 2004, p. 2). I use this framework to determine how biotechnology companies view the development of CNT-based and lipid nanoparticle mRNA vaccines as a catalyst to a future that leads to future innovation, advancement in public safety, and public health equality. In particular, I look into how the biotechnology companies, Luna Labs and Pfizer, engage in co-production with patients and healthcare personnel by addressing the technical controversies that surround vaccine production currently.

Methods:

I collected primary and secondary sources that focus on the efforts of biotechnology companies such as Luna Labs and Pfizer to address social issues such as vaccine hesitancy, accessibility, and innovation through mRNA vaccines. I included Luna Labs in the analysis because they are a smaller company than Pfizer and therefore offer a different perspective in terms of who they advertise for on their website. They are appealing to a different audience than Pfizer. I used discourse analysis to analyze the intent of the biotechnology companies. In particular, I looked at the language used on their websites to depict their vision for the mRNA vaccines they have worked on or are working on.

The secondary sources I used divulge into the scientific motivations for mRNA vaccines to understand how they help the biotechnology companies achieve their visions. I focused on sources from the last 5 years. The primary sources are mainly from Pfizer and Luna Labs.

In my review of the literature, I focused on the social issues that surround vaccines such as vaccine accessibility and vaccine hesitancy. I chose this order because vaccine accessibility plays a role in vaccine hesitancy to an extent. Then, I introduced mRNA vaccines as a response to both issues. I highlighted keywords and recurring themes in each issue. I used these keywords to identify the improvements of mRNA vaccines over conventional vaccines. In my analysis, I use this information to determine how biotechnology companies respond to these issues and what they envision for a desirable future in regards to these concerns.

Analysis:

Through the delivery methods of carbon nanotubes and lipid nanoparticles, biotechnology companies present imaginaries that promote vaccines as a solution to eradicate diseases that affect the majority of the world. Biotechnology companies are the actors that create the vaccines, and this means they are also responsible for devising new delivery methods for mRNA vaccines. In this way, they are involved in the co-production of vaccines. They take the discourses and complaints about current vaccines to drive scientific research and evolve the fundamental ideas of vaccines development.

Biotechnology companies aim to eradicate disease by making vaccine accessibility equitable through their CNT and lipid nanoparticle-based vaccines. Luna Labs states that their CNT vaccine platform for HIV-1 is suited “ for addressing global health concerns” and can be “easily produced from widely available and low-cost compounds” (*NanoVac*, 2022). No current viable vaccine options are available for HIV-1. The cost of production using conventional vaccine methods to combat HIV-1 is very costly, especially for countries that have a population with a high risk for HIV-1. By using CNTs to deliver mRNA, they hope to reduce the cost of production. The desire for low-cost production ultimately allows for lower pricing which can increase the accessibility of the vaccine globally. More countries can access vaccines for their population, and this is the first step towards equitable access to vaccines. The language that Luna Labs uses, by emphasizing 'widely available' and 'global health concerns', encourages an imaginary world where humanity as a whole is healthy together and equally through vaccination. Luna Labs further addresses this issue by highlighting that CNTs increase the stability of mRNA vaccines during refrigeration (Xu et al., 2023). Increasing the stability of the vaccine allows for better and low-cost distribution. As mentioned in the literature review, vaccine distribution is one of the main contributors to vaccine inaccessibility. By directly targeting this issue in their design specifications, Luna Labs acknowledges that increasing stability of the vaccine will aid in the distribution of the vaccine, and thus encourage social equality. This helps them fulfill their goal of "addressing global health concerns".

Similarly, Pfizer also addresses the vaccine accessibility issue through their COVID-19 lipid nanoparticles-based vaccine. In particular, they state they are "working to develop and distribute vaccines throughout the world" and protect all age groups (*Vaccines | Pfizer | Pfizer*, n.d.). They also state that they "remain committed to working toward broad, equitable, and affordable access to Pfizer and BioNTech's COVID-19 vaccine" (*Pfizer Coronavirus Resources: Covid-19 Updates, News, Information | Pfizer*, n.d.). Their language and tone paint the picture of hope through innovation using this new technology. By cracking the code on mRNA vaccines, they are able to provide vaccines at levels never seen before. Pfizer specifically mentions all age groups to address inequality of vaccine research across age groups. By specifically claiming that their COVID-19 lipid-nanoparticle vaccines will promote equitable access and using language such as ‘throughout the world’, Pfizer acknowledges that there is a current issue of social inequality and they envision a world where vaccine accessibility is equal with their technology.

Both Luna Labs and Pfizer, through the co-production process, see the potential of CNTs and lipid nanoparticles not only as a delivery method for mRNA vaccines but also as vehicles for a socially equitable world. To them, this world consists of equal access to their vaccines because the cost is low and the quality of the vaccine remains the same no matter how long the vaccine is stored. As mentioned before, the audience of the work of Pfizer and Luna Labs is different due to their size difference. Luna Labs promotes this imaginary because they are trying to convince researchers that CNTs are a solution to the problems that make other attempts at creating an HIV vaccine inaccessible. This can lead to more funding for their research and attract partners for future research. Pfizer promotes this imaginary to appeal to the general public because targeting vaccine accessibility creates more demand for vaccines and helps Pfizer expand their business.

Biotechnology companies aim to eradicate disease by addressing vaccine hesitancy through careful considerations of safety and ultimately envision a world where people have security in the public health systems. Luna Labs developed CNTVac with the specific goal of requiring less lipid to eliminate potential adverse effects (*NanoVac*, 2022). One of the concerns for vaccine hesitancy is the safety of the vaccines. Previous conventional vaccines were often accompanied with adverse side effects that deterred people from receiving vaccines. By emphasizing the need to eliminate potential adverse effects, Luna Labs directly addresses the concern of vaccine hesitancy. They understand that the way to effectively prevent disease is by earning the trust of the public in CNT technology. They see their vaccine as a way to build this trust and instill faith in public health by addressing the public’s concerns about the safety of the vaccine. Interestingly, Luna Labs is researching CNTs as an alternative to the lipid-nanoparticle COVID-19 vaccine introduced by Pfizer and BioNTech which resulted in increased vaccine hesitancy. They present this to other researchers in hopes that this technology will be used more and seen as an improvement on previous methods.

On the other hand, Pfizer uses the tool of education to emphasize why their lipid nanoparticle COVID-19 vaccine is safe and dispel the myths about vaccines in general. They address myths such as the lack of need for vaccines, vaccines containing harmful ingredients, and vaccines causing infections (*Get the Facts About Vaccinations*, n.d.). They also participate in educational efforts such as the COVID-19 Education and Equity Project to address vaccine hesitancy. They also engage with patient advocacy groups to understand patients' experiences and discuss side effects (*For Education, Support, and Assistance, Patient Advocacy Groups Can Help*, n.d.) Pfizer has open access to safety data sheets for all of their products including the mRNA Pfizer-BioNTech COVID-19 Vaccine. Vaccine hesitancy became more prevalent upon the approval and distribution of the COVID-19 pandemic. Pfizer aims to directly address the main concerns laid out for vaccines that were mentioned before. The language used on their website aims to create an image of safety and security in the new mRNA technology that they used in their COVID -19 vaccine. The inclusion of the data sheets aims to create open communication about the products that can be referenced in discussions of vaccine hesitancy. Additionally, they are constantly revising their formulation to make a better vaccine and by engaging with the public about their concerns, they express how they want to see a world where the public feels safe with the vaccine. By engaging patients and healthcare personnel in the production process, biotechnology companies engage in co-production to improve the state of vaccines. Biotechnology companies acknowledge that the development of vaccines is not isolated from the willingness of the public to get vaccinated and acknowledge the co-production of both processes in regards to each other. This open communication builds trust and security in the solutions to public health issues by addressing issues with vaccine safety into their design.

Biotechnology companies portray a sociotechnical imaginary where CNT and lipid-nanoparticle mRNA vaccines are tools for global economic development. The CNTs and lipid-nanoparticle mRNA vaccines can be manufactured at a faster rate (Jackson et al., 2020). From this standpoint, people can receive vaccines quicker which results in a healthier population, and therefore more people can contribute to the economy. When the COVID-19 pandemic hit, the main goal for biotechnology companies such as Pfizer was to quickly create a COVID-19 vaccine. They were encouraged by governments to tackle this public health crisis. However, the biggest incentive for creating a COVID-19 vaccine, despite the challenge it presented, was the financial gain for the company. After all, at the end of the day, the goal of a company is to make money. In 2021, Pfizer reported that their annual revenue for the year increased 95% from 2020, which was an unprecedented increase in annual revenue based on the patterns from previous years (*Pfizer's Financial Performance in 2021*, n.d.). They were able to create a vaccine for the pandemic before other companies through the use of lipid nanoparticle-based mRNA vaccines. One of the main attractions of mRNA vaccines for biotechnology companies is the low-cost production process and fast manufacturing. This is due to the extensive ability to transcribe mRNA. The process is cell-free and scalable which means that companies do not have to wait for cells to grow and continuously maintain these cells as they would have to with conventional methods (Jackson et al., 2020). Therefore, this speeds up the time it takes to manufacture mRNA vaccines. A faster and low-cost manufacturing process meant that they could be one of the first companies to maximize their profit from the vaccine.

However, this is not how Pfizer portrays the innovation in manufacturing processing for vaccines. Instead, they portray it as an innovation that advances public health and therefore global economic development. In 2023, Pfizer sponsored an Economist Impact report into the global economic effect of the pandemic. They reported a monetary loss of $2 trillion in GDP combined of OECD and 8 Latin American countries as a result of COVID-19 (Michael, 2023). They also report that if infection rates are comparable to 2022, it will result in a combined $21.6 billion decrease in GDP globally in 2025 (Michael, 2023). They urge that “long-term declines in GDP can be reduced by prioritizing resilience against covid-19 and other threats” and that vaccination has already prevented 14.4 million deaths due to COVID-19 (Michael, 2023, pp.7, 29). Through this report, Pfizer demonstrates how vaccination stimulated the global economy. When more people are vaccinated, fewer people get sick, which means more people can work. When more people can work, we see more innovation and therefore economic growth. Pfizer portrays the lipid-nanoparticle-based COVID-19 vaccine as a medium towards economic growth by preventing disease. The lipid nanoparticles technology allows Pfizer to do this quickly because they can manufacture the vaccine more efficiently than with other methods. By publishing this economic growth, Pfizer turns attention away from their own financial gain with the vaccine technology. In turn, Pfizer pushes the imaginary that lipid-nanoparticle-based vaccines can stimulate the economy by eliminating disease.

While it is true that Pfizer does not hide their personal economic gain as their financial performance is published on their website, it is not the main imaginary they are creating. It takes a specific search on their website to access this material. On the other hand, Pfizer has openly published reports about the US and global economic effects of vaccines as seen through the Economist Impact report. Additionally, Pfizer pushes imaginaries that demonstrate the vaccine as a solution to public health issues rather than highlight their personal gain as demonstrated by the emphasis on vaccine accessibility and safety. A sociotechnical imaginary must fit with the existing cultural norms and morals. Therefore, Pfizer focuses on the global boost in economy due to the vaccines to appeal to these norms.

Conclusion:

Biotechnology companies have imaginaries outside of the surface-level goals of making money and eradicating disease. They aim to achieve these goals by promoting equality in vaccine accessibility by easing the vaccine distribution process. They also see a future for trust in public health measures by directly addressing vaccine hesitancy concerns in the design of their vaccines. Finally, biotechnology companies emphasize new vaccine methods as a venue for global economic growth.

Future researchers can build off this project by a different framework such as social construction of technology (SCOT) to analyze how relevant social groups of the technology influence the imaginaries presented by the companies. SCOT states that technology is influenced by the social interests of various relevant social groups. Each social group holds a shared meaning of the technology amongst themselves. While CNTs are a relatively new technology, it is necessary to understand who influences their development and how they contribute to the sociotechnical imaginaries laid out in this paper. Additionally, future research can explore how the real actions of these biotechnology companies compare to the sociotechnical imaginaries they promote to the public. It is important to analyze the actions of these companies and hold them accountable if they are practicing engineering techniques that counter these imaginaries.

Understanding the sociotechnical imaginaries portrayed by biotechnology companies provides a roadmap for future technology to build off of as progress is made to realize these imaginaries. As seen with the potential for innovation through mRNA, there are possibilities to solve otherwise “impossible problems” such as cancer. Recognizing the social influences and potential impacts for CNT and lipid nanoparticle-based vaccines encourages engineers to develop technology for the good of society and act off their thoughts and imaginaries through action.

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