MSA Independent Research Log

I Search Research: All About Vaccines

Why are you researching this topic? **Although I really wanted to find something that could link something related to psychology and something related to medicine together, seeing as my topic for my APA Lit Review didn't satisfy my desire to know if psychology is really something I'm interested in, I couldn't find another topic that would interest me again and would bridge the gap between the two fields. However, being inspired by getting the short end when it comes to side effects of the COVID-19 vaccine, I suddenly found myself interested in wanting to know more about vaccinations, specifically the molecular side of them because of how the COVID-19 vaccines are of a new type, mRNA. I decided to broaden my topic to simply every aspect of vaccines and have the molecular workings of vaccines be a subtopic.**

Language of this Topic:

- **Vaccine** - a type of drug/substance that contains antigens for a particular pathogen; when inserted into an individual, the immune system is prompted to create antibodies against the antigens, creating immunity for the particular pathogen; the different types are live attenuated, inactivated, subunit, *DNA*, *mRNA,* and *vectored*
- **Pathogen** - a disease-causing bacteria or virus
- **Antigen** - any part of a pathogen/substance that allows it to be identified uniquely; when inserted into an organism, antibodies can be made
- **Antibody** - a protein that has a specific shape and function, which is to recognize and bind to a particular pathogen to fight it off
- **Macrophage -** white blood cells that are a part of the immune system; digest pathogen molecules via phagocytosis
    - **B-lymphocytes -** type of macrophage that prompts cell-mediated immunity
    - **T-lymphocytes** - type of macrophage that prompts humoral immunity
- **Herd immunity** - the state in which protection against a disease has been obtained by way of a majority of the population either obtaining immunity from either natural infection or vaccine
- **"Vaccine hesitancy"** - describes when certain individuals refuse to or delay getting a vaccine due some notion, such as vaccines causing autism

Tips for About-Point-React posts--

About--Think big picture. What is this topic, article, expert, source about generally, and what drew you to it?

Point--What did you know prior to your research? What did you learn? Bulleted points are fine. Copy/pasting is NOT OKAY. **Paraphrase your findings.**

React--Use the following to help you flesh out a react that will be helpful to you in the future:

- Why is the topic important--to you, to our area, to the world?
- Where could you go with this topic if given more time?
- What other questions could you explore associated with it?
- What potential capstone (job shadowing/service learning) or research ideas does it inspire in you?
- What would you need to know, understand, experience, or be able to do to complete extended work with this topic?

NOTE: *Italics* within the "Point" section of each post indicate prior knowledge/personal commentary on the research but not actual information stemming from the source.

Research Post/Question 1: **What are vaccines? (Senior Project)**

About:

Despite being hampered by the ongoing pandemic, Joyce Poon was still able to create a presentation on the importance of vaccines and give an general overview on them, including information such as the various types of vaccines. As part of her research, she did an interview with an RN who was, at the time, administering vaccines to Californians against the flu. Being interested in vaccines as a result of the pandemic and the vaccines currently being used to fight against it, I was interested from the onset in this Senior Project as it is contemporary to the current pandemic; it describes vaccines in the current context of the pandemic all the while giving the crucial general information that I wanted to know before going to any more in-depth research. Her product, a podcast which I also used for research below, is also part of what drew me to the source, as it gave greater explanations and details in regards to the brief overview she gave during the "Senior Presentation" part.

Point:

Prior Knowledge:

- Vaccines are essential and are encouraged by the whole health community to be administered to everyone, as they prevent widespread disease outbreaks through allowing everyone to be immune to the disease that the vaccination fights against.
- Despite being encouraged, there exists certain portions of the population that are against vaccinations and the prospect of being vaccinated for one reason or another.

Knowledge Obtained:

Senior Presentation:

- Vaccines were only first made in 1796 with Edward Jenner's innovation in the medical field to practically eradicate smallpox with a vaccination against the disease
- Vaccines protect against disease by producing or at least encouraging antibodies to form, which fend off and fight against the illness they're meant for (*prior knowledge here: antibodies are proteins that are created by the organisms' cells that have a specific shape and therefore specific function - each antibody is tailored to recognize and bind to a specific disease-causing molecule and fend it off)*
- There are four types of vaccines typically administered to the public, all of which in some manner help form antibodies created by the organism to fend off a specific disease (as is the function of antibodies):

    - Live attenuated vaccines, which use still live but weaker/less strong form of the disease-causing particle/germ
    - Inactivated vaccines, which use a “kill form of the germ”
    - Toxoid vaccines, which use a “toxin created by the germ”
    - Subunit/Recombinant/Polysaccharide/Conjugate vaccines, which take just a piece of the disease-causing germ to allow recognition in that way
- In terms of vaccines, herd immunity refers to the fact that vaccines, by way of how they allow for individuals to be better protected against disease, allow for entire populations to be safer from obtaining the specific disease that the vaccine fights against if administered on a widespread scale
- Vaccine hesitancy is founded upon certain unanswered questions and conceptions held by certain people, such as:
    - the false idea that vaccines cause autism (yes, some side effects are present with vaccines, *such as with the COVID-19 vaccines*, but nothing has been found to demonstrate that vaccines lead to autism) and
    - concerns about vaccines’ safety/efficacy (these are undermined/unfounded when considering how vaccines must go through rigorous testing/trials before ever being introduced to the public in addition to close examinations by health organizations)
    - *NOT a misconception* vaccine hesitancy can also simply be a product of an underlying health condition, such as someone being immunocompromised
- The misconceptions that then lead to vaccine hesitancy can then also lead to serious societal effects, such as herd immunity no longer being attainable with a specific disease
- Vaccines go along with the field of microbiology (vaccines may even be considered a subset of microbiology)

Podcast Episode 1:

- “Microbes”/bacteria themselves can be used to make antibiotics and vaccines against other bacteria that are disease-causing, which is where the field of microbiology comes into play
    - Plasmids, which can be thought of as an extra file of DNA in addition to the single, circular chromosome found in bacteria, have genes that code for adaptive benefits for the bacteria in which they are found
    - Pathogens are the name of bacteria that cause illness; the reason why they can lead to rapid development of illness upon entering organisms is that they can reproduce quickly through binary fission given the correct environment
- Viruses, which are not a type of prokaryote or eukaryote, are made of a capsid and some genetic material in the form of DNA
- Exogenous infection = infection gained from surroundings (i.e. people, animals, etc.)
    - Pathogen/microbe needs to then adhere to the host organism using one of its organelles, and once it does, it can then start to reproduce and fend off immune system

Podcast Episode 2:

- Vaccines are NOT antimicrobial agents, which are defined as “any natural or synthetic substance that kills or inhibits the growth of a microorganism” (most known is antibiotics)
    - Antibiotics have wide range of effectivity because of their property of selective toxicity, caused by the oligosaccharides on the outside of the bacteria

    - Antibiotic resistance can be caused by the bacteria's production of enzymes that destroy the antibiotics, a change in the permeability of the bacteria's plasma membrane, the changing of a bacteria's amino acid, and ejection of the drug by the bacteria in the cell
- Viruses cause most symptoms of illnesses despite antibiotics being overprescribed for viral symptoms
- When it comes to fighting off infections, white blood cells play a major role, as they contain the major disease-fighting particles: macrophages - B-lymphocytes and T-lymphocytes, which are what digest the invading bacteria
    - Antigens = parts of the now-eaten (by the macrophages) bacteria that allow the immune system to recognize that something is amiss when it comes to microbial health and respond by producing antibodies
    - B-lymphocytes fight off antigens by producing antibodies, T-lymphocytes fight off infected cells
    - Once infection is fought off, to remember how to fight it again, some T-lymphocytes are kept by the organism's immune system so that the antigens will be recognized
- Live attenuated vaccines are manufactured in laboratories and are basically modified forms of the bacteria that cause illness - they have been weakened so that they do not cause disease but are allowed to maintain their regular shape and replication properties so that the immune system can recognize them to produce future immunity against future encounters with potential live, non-attenuated bacteria
    - Can be best described by "natural infection...leading the path to artificial immunity"
- Toxoid vaccines take the parts of a cell that are the disease-causing ones, called toxins, which go into the bloodstreams of the organism, and modify them to create an immune response
- Subunit/recombinant/polysaccharide/conjugate vaccines are like toxoid vaccines except they simply just take a specific part of the bacteria such as its protein or capsid and use it in the vaccine
    - Can be used by immunocompromised
- Inactivated vaccine use "killed version" of the pathogen and therefore require booster shots
    - Booster shots are used to boost immunity with an additional dose; need to boost antibody levels back to decent levels

Podcast Episode 3:

- Antibodies are a type of immunoglobulin, which are proteins produced by the immune system that do as proteins normally do to fend off disease
- PCR tests make copies of certain sections of DNA that are important to a specific subset of diseases, which leads to its efficiency/speed - can identify the genetic material of bacteria that causes certain diseases faster
- A high percentage of vaccinations in the population leads to herd immunity (high % of population has immunity, thus reducing disease transmission) which leads to disease eradication
    - Herd immunity provides protection to those who cannot receive vaccines
- Additional reasons for vaccine hesitancy:
    - Religious beliefs
    - The notion that vaccinations lead to artificial immunity, which is not as beneficial as natural immunity
    - The stigma of vaccines being 'unknown chemicals' and the connotation associated with that
- Better education and awareness campaigns should be done so that people no longer maintain these false, unwarranted beliefs against vaccines

React:

Although there were some points throughout the Senior Presentation and podcast that I felt were left a little vague, I came away with a great general understanding of vaccines and their important role in public health. The most important takeaway I took from the information that she and Naomi (her partner in creating the podcast) presented are the new starting points for further research I could do in regards to vaccines, such as how they work on the molecular level and further in-depth research on the stigmas held against vaccines, which is ultimately what I hoped for in starting out with the Senior Presentation as my first APR. In regards to the substance of the information itself, there appears to be a double-edged sword in how it was presented; it was mostly easy to understand with simple language throughout the podcast, but for certain items, such as the different types of vaccines past live attenuated, the simplification of the information made understanding the information harder. Although this wasn't necessarily the main point of listening to the podcast, I can tell that having a background in microbiology would help with this research, as the world of vaccinations and the world of microbiology, which was discussed by Naomi, do have some overlap in some aspects. I hope to see if it will truly be helpful/be a field in which I'm interested in by taking MG Microbiology next year.

One more note sort of unrelated to the above: Although my Senior Project will be different from theirs (with the hope that the effects of the pandemic have subsided), I found the possibility of doing a podcast quite interesting. This could work if my Senior Project, such as with the field of vaccines, is in a field that would require or benefit from greater awareness about my chosen topic.

Sources:

Poon, J. (2021, March 29). *The Importance of Vaccinations and Maintaining Global Health*. Presentation, Virginia Beach. **(under "Senior Presentation")**

Williams, N. & Poon, J. (Hosts). (2020). *Under the Scope* [Audio podcast]. Anchor. https://anchor.fm/underthescope101 **(under "Podcast Episode #)**

Research Post/Question 2: **How do the different types of vaccines work on the molecular level? (Google Scholar)**

About:

Vetter and his coauthors, who seem to be involved with various pharmaceutical companies, such as GSK and Pfizer, created their source to simply inform the public about the differing types of vaccines in an effort to decrease vaccine hesitancy and the misinformation about them. To do this, they discuss each of the different types of vaccines, going over how they are made, what each one contains in regards to the type of antigen they possess, and various relevant examples of each. They also give a brief discussion of how vaccines work in regards to prompting the immune system with their antigens, but this had to be supplemented by an additional source. Although they covered the least helpful aspect, the various examples of each, the most for each type of vaccine, what really stood out in this source was its linearity; it never branched out into unnecessary complexity that would have been difficult to understand. This aligns with the purpose of their source to hopefully provide more clarity to reduce vaccine hesitancy.

Although this is only a specific chapter in their expansive book, Janeway, Jr. and his coauthors, again, simply aim to inform the general public about immunobiology and the immune system. Their intended audience is meant for postsecondary students and readers, but none of their language in the small sample of the book I read was ever too lofty; in fact, I thought it aligned well with the type of language used in my biology class. This is what drew me to this source, as I wasn't looking for anything particularly advanced or in-depth. I just wanted something to help me understand what I gleaned from the main source by Vetter in regards to the process from vaccine to antibody development, and this filled that niche. Janeway, Jr.'s source covers the humoral aspect of the immune system, which basically is the part of the immune system that deals with antibodies, and the three ways in which antibodies work. It also furthers the initial explanation of macrophages given by Joyce in her podcast.

Pöri's thesis was mainly used as a means of corroborating the information given in Vetter's source and also as a means of confirming the notions I held as true but were not explicitly mentioned in the first article. Again, the simplicity in which every topic is described was what drew me to this source, as I was not looking for anything too lofty that would confuse what I had already learned. It gives a more in-depth overview of vaccines than what was given in the Senior Project, covering topics such as the future of vaccines, the various vaccine types, and the progression of a vaccine's distribution to the public. Although there was a lot of repeated information given in this source that was already gleaned from the first source, what makes up for it is that there was additional information that did not pertain to the research question at hand but could serve as prior knowledge for another research question. For example, the progression of a vaccine could be helpful for a research question about vaccine hesitancy.

Point:

Prior Knowledge:

- Macrophages, such as B-lymphocytes and T-lymphocytes, are the molecular units of the natural immune response to an invading pathogen
- Live attenuated, toxoid, subunit, and inactivated vaccines are the four types of vaccines
    - Live attenuated vaccines contain a modified form of the pathogen that allows the organism's immune response to recognize the vaccine for any future encounters with a real/natural form of the pathogen
    - Toxoid vaccines use specific disease-causing parts of the pathogen to develop the same response as live attenuated vaccines
    - Subunit vaccines use non disease-causing parts of the pathogen
    - Inactivated vaccines use "killed version" of the pathogen

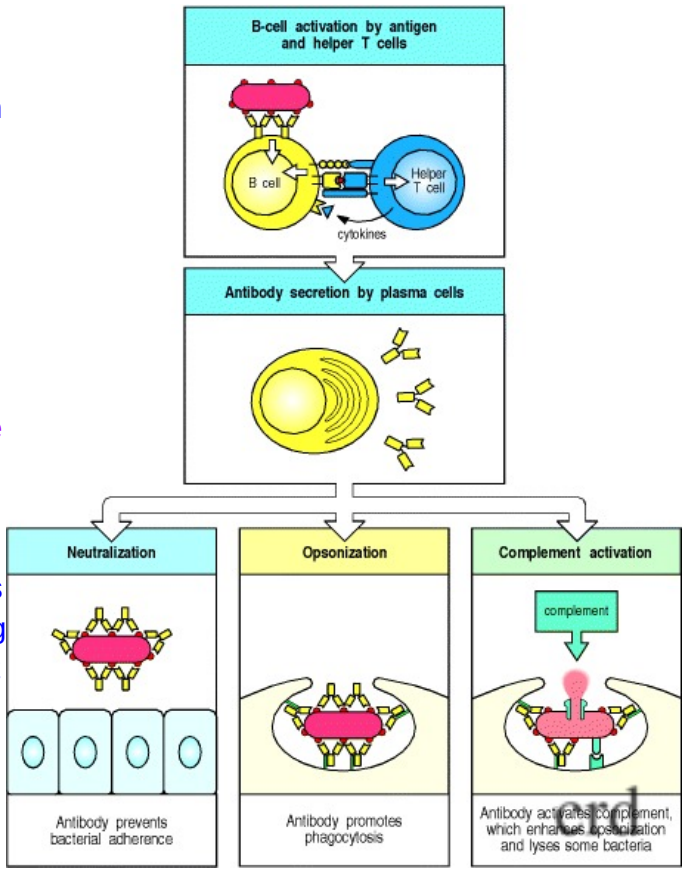
Knowledge Obtained:

General Information:

- Vaccines provide what is called "active immunity" - when the body makes the antibodies when prompted by natural or artificial source (i.e. vaccine antigens)
- The different types of vaccines exist each to serve a different purpose against a particular disease; each one has their particular benefits and drawbacks towards any one type of virus

<u>The Immune System as It Relates to Vaccines:</u>

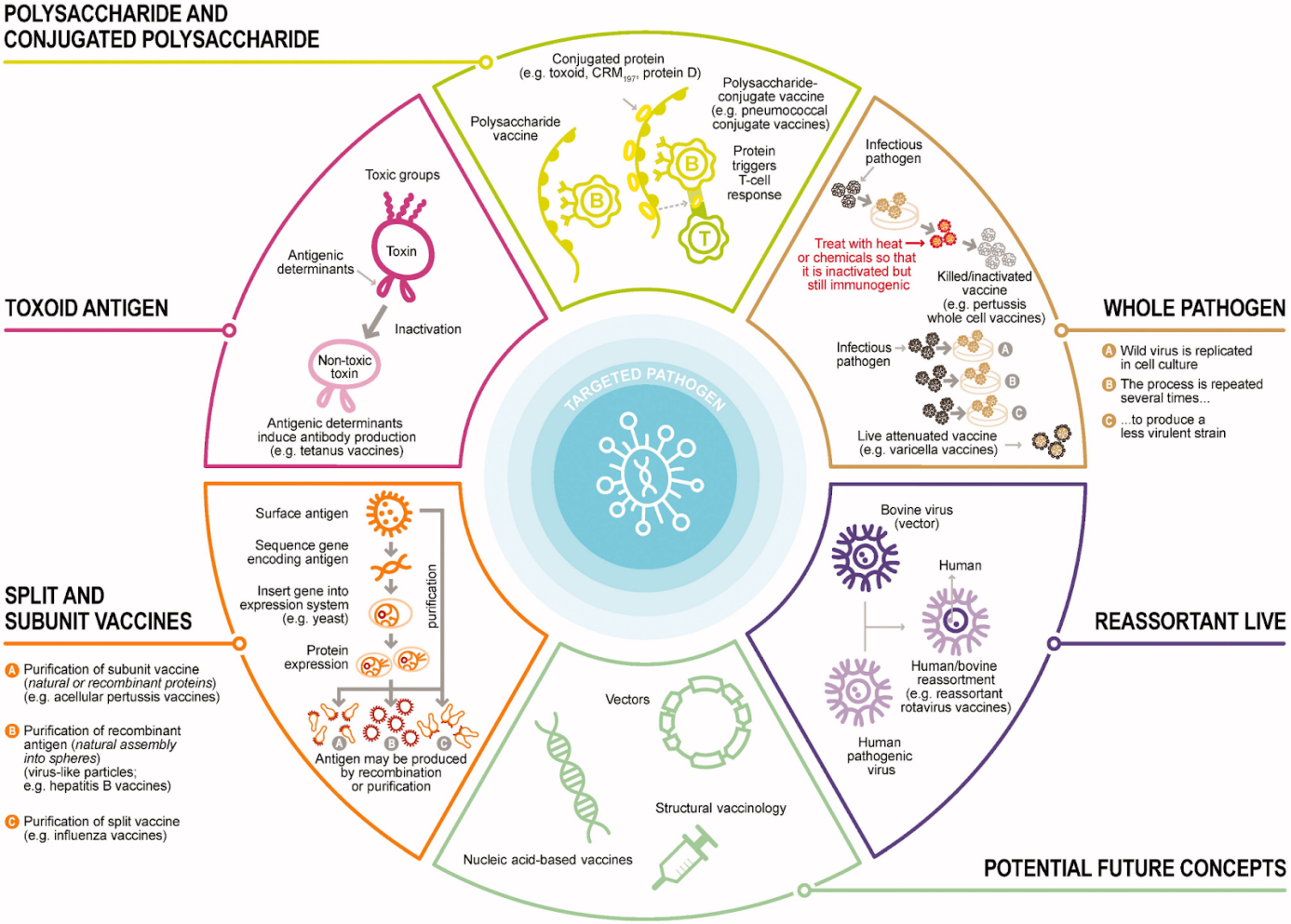
- In general, with their contents, vaccines stimulate adaptive immunity, made of humoral and cell-mediated immunity, as they simply force cells to create their own antibodies and macrophages from the vaccine's antigens (coming from the original pathogen)
    - Lymphocytes are white blood cells
    - Humoral immunity = immunity created by the B-lymphocytes producing antibodies within the bloodstream/fluids (hence humoral)
        - Specifically, the B-lymphocytes are able to split into two different cells: the cells that contribute to the memory of the immune system (most likely serving as templates for future antibody production) and the cells that actually produce antibodies
    - Cell-mediated immunity = occurs within cells by the T-lymphocytes, which help B-lymphocytes in producing antibodies
        - Refers to how infected cells are destroyed by the T-lymphocytes
- Antibodies work by a method of three ways (picture comes from this source on the molecular level to prevent pathogens from infecting cells):
    - Neutralization: before the pathogen (disease-causing bacteria and viruses) even gets a chance to bind to the cell it wants to infect and enters said cell, antibodies recognize and bind to the pathogen molecule, which prevents it from ever adhering to any cell's surface
        - The following two require initial neutralization by antibodies of the pathogen and fight off against bacteria that do not necessarily need to infect the cell to reproduce
    - Opsonization: after antibodies bind to the pathogen, the antibodies take the pathogen to specific cells that are designed to eat wastes and bacteria in a process called phagocytosis (*a form of bulk, active transport that involves forming vesicles from the plasma membrane to intake large macromolecules/particles)*
    - Complement activation: similar to opsonization, complement activation does as its name suggests, as the bound antibodies can activate the complement system, which are proteins produced by plasma cells designed specifically to attack invading pathogens, aiding in the bacteria's phagocytic digestion or killing the bacteria itself
- The "immunological memory" that is created by vaccination refers to how the antibodies produced as a result of the vaccination stick around after the antigens of the vaccine are gone, increasing/being produced in bulk only when needed against a natural form of the pathogen
- Vaccines stimulate an immune response with weakened pathogens that is very similar to the immune response to a natural version of the pathogen, leading the way for immunity without the severe symptoms associated with the natural pathogen



- Herd immunity, or the state of a large population of people being immune against a certain disease, thus resulting in its lack of transmission, can also be achieved through applying vaccinations against a specific subset of the population that

is most susceptible to the disease and is most prone to allowing it to infect others

- *surprising factoid* It's fairly understandable that a lot of the general public are not aware of the inner workings of vaccines, as they're not necessarily expected to do know every single little detail in healthcare, but apparently some doctors and healthcare professionals are also unaware of the molecular biology behind vaccines as well
- Virulent/virulence = basically meaning disease-causing
- General Overview of the Different Vaccines:



- These vaccines are so named for the type of antigen they contain to evoke an immune response out of the immune system
- Inactivated, subunit, and toxoid vaccines are all forms of non-live vaccines, which is in contrast to the live attenuated vaccines
- This means that they are not virulent at all and have no chance of becoming virulent, which is again, in contrast to live attenuated vaccines
- One downside to these non-live vaccines is that they may require more doses than live attenuated vaccines so that immunity to a specific disease-causing pathogen can be maintained, either through booster shots or just simply readministration of the original vaccine
- Non-live vaccines, according with the different types within the umbrella term, can be non-live versions of entire pathogens or only parts of the pathogen

Future:

- Vectored and DNA/RNA vaccines are currently being experimented with to see if they'd be effective in addition to different ways to administer the existing types of vaccines, such as through the mouth, nose, or through the skin without a needle
    - DNA vaccines involve isolating the gene and putting it into a certain bacteria as one of its plasmids (i.e. additional DNA of the bacteria), which delivers the DNA/gene that expresses the antigen to a cell via typical infection; then, the gene is expressed to create the antigen, forming the immune response
- In an attempt to innovate the domain of having to return for additional booster shots or something of the like, another future possibility could be having one shot with multiple packages/polymers that should release their contents at the appropriate time, thus releasing the need of additional shots

Live Attenuated:

- These are typically viruses (but are typically defined as being pathogens in general, meaning bacteria could also be used to make live attenuated vaccines) that are changed in some fashion so that they do not cause severe symptoms that are typically associated with the virus in its natural form
    - The reason why viruses are typically the ones chosen for live attenuated vaccines is because of the general simplicity of viruses compared to bacteria; they have less DNA and therefor are easier to control
- Live attenuated vaccines are made either by having the virus successively reproduce in cultures, which reduces their severity, or having the virus instead reproduce in low temperatures
    - *(just an assumption, as the article doesn't say this necessarily but sort of implies it) Natural selection plays a role in having the virus strain be weakened, as being put in those two scenarios, only the strains of the virus that do well in those conditions will reproduce, causing the virus to be less severe for humans*
        - In terms of the former, the virus becomes better in reproducing in manufactured cell cultures but worse at infecting human cells
        - In terms of the latter, by the end, the strain of the virus that exists is good at reproducing under low temperature conditions but worse at reproducing at the higher, human body temperatures
- Live attenuated vaccines still, at its heart, contain a form of the natural virus, albeit weakened, so the immune response caused by the antigens present in these types of vaccines is similar to that caused by a natural form of the virus infecting a human
- With the weakened antigens, the human immune system is given more time to produce antibodies against the virus
    - This means it requires less doses of the vaccine (typically just 1 or 2 is good enough for immunity)
- Interesting fact: live attenuated vaccines still are a live form of the pathogen, so spread and transmission can occur, so for example, if a single person in a family is vaccinated with a live attenuated vaccine, transmission can occur theoretically from that vaccinated individual to another family member
    - Can be seen as both a positive and a negative, as it depends on who the weakened form of the virus is transmitted to (can technically cause **"**vaccination**"** in strong quotation marks in those family members)

- Some complications that can occur with live attenuated vaccines: immunocompromised people should stray away from live attenuated vaccines unless truly necessary, can cause complications during pregnancy with possible infection of developing fetus, and the weakened form of the virus/pathogen can still have a rare of chance of going back into a highly-virulent form of itself
- Have short shelf life and require storage in cooler temperatures
- Many of the live attenuated vaccines used today, such as those against yellow fever, measles, and mumps, were developed through the successive culturing process

Inactivated:

- A live form of an entire pathogen is taken and is basically killed off through one of a variety of methods, such as heat, radiation, or chemicals
- As a result, the pathogen cannot reproduce and cause symptoms in humans but still remains intact in terms of form, allowing the now-dead pathogen to still create an immune response when present in humans - allows for creation of antibodies and therefore allows the immune system to perform according to methods of antibodies above
- This type of vaccine can be taken by the immunocompromised, but there are still booster/additional shots associated with inactivated vaccines to ensure immunity is maintained over a lifetime
- Some examples of inactivated vaccines fight against hepatitis A and rabies

Subunit (Protein, Toxoid, VLPs, Polysaccharide, and Polysaccharide Conjugate):

- In contrast to inactivated and live attenuated vaccines, subunit vaccines, as the name implies, contain only a part of the pathogenic molecule, whether it be a specific protein, polysaccharide (*the one that jumps out to me most are the oligosaccharides found on the exterior of cells' plasma membrane, which function for cell-to-cell communication and regulation*), or another part specifically for viruses called "virus-like particles" VLPs)
- Also do not contain any actual genetic material of the pathogen, disabling any antigen found in these vaccines from reproducing
- Because they only contain a part of the whole pathogen and therefore less antigens, subunit vaccines elicit a lesser frequency of severe symptoms while at the same time only providing much more limited immunity in comparison to live attenuated/inactivated, whole-particle vaccines
    - This can also be due to the process in which the part of the pathogen is isolated, as in said process, some parts of the virus that would otherwise create immunity are lost
- There are multiple subcategories of subunit vaccines, such as protein vaccines, toxoid vaccines, VLP vaccines, polysaccharide vaccines, and polysaccharide conjugate vaccines
- Adjuvants are any type of molecule that can help the immune system develop its response against a vaccine, which is most typically used with subunit vaccines due to them having lesser antigens and therefore less of a possibility of a greater immune response (not required for live attenuated because of the antigens/pathogens being live and able to reproduce)
- These are helpful to reduce number of doses, number of antigens required, and allow people such as the immunocompromised to have a better immune response to the vaccine
    - Aluminum salts are the most common and most frequently used adjuvant

<u>Protein/Recombinant:</u>

- These can be produced either starting from the entire pathogenic molecule and isolating the protein or can be created with "recombinant genetic engineering"

    - "Recombinant genetic engineering" entails taking the gene that expresses the instructions to create the desired protein from the pathogen itself and injecting it into cell cultures which then produce the protein themselves
- Flu vaccines are a type of protein/recombinant vaccines, as each individual vaccine now contain parts from the multiple strains of the flu that are expected to be transmitted for a particular flu season
    - With the definition of subunit vaccines, how humans now have to get a new flu vaccine each year makes sense, as the immunity can only last so long (in tandem with the fact that which strains are being transmitted are changing from year to year)
- Generally, there are less antigens (as expected with subunit vaccines) in protein vaccines that there are in whole-pathogen vaccines, as is demonstrated with acellular pertussis vaccines
- Hepatitis B vaccines are examples of recombinant vaccines, as they insert a gene into cell cultures that expresses a specific protein found on the surface of hepatitis B cells to produce the protein, which is then purified from the culture
- More examples of recombinant vaccines include vaccines against malaria
- "Reverse vaccinology" is a term that describes how some vaccines are created by simply going straight to the genome of a pathogen and trying to pick out, through experimentation, which parts of the pathogen, whether protein or polysaccharide or other, can create an effective immune response
    - It opens up the possibility of finding new parts of a particular pathogen that aren't expressed frequently (*probably due to natural selection*) that could be used for a vaccine
    - For example, the *Neisseria meningitidis* serogroup B only typically produced polysaccharides that were similar to human ones, thus presenting a challenge in finding a proper part to isolate, but with "reverse vaccinology," new polysaccharide genes were found that were better to use for the human immune system
- Recombinant vaccines can also struggle due to some pathogens' variety in what they express and their genetic makeup

<u>Toxoid:</u>

- A type of subunit vaccine, these toxoid vaccines are produced through the typical non-live way, as their process of production involves purifying/destroying the toxin that is released by bacteria and is responsible for causing disease, leaving behind toxoids
- Toxoids are the name of the now-inactivated toxin particles, which are allowed to function as the inactivated pathogens would in an inactivated vaccine except on a much smaller scale
    - The toxoids still retain their capacity of having something to bind to so that the immune system may recognize them and produce antibodies against the natural form of the toxin
- Toxoid vaccines require booster shots, as they require a replenishment of new antibodies to be continually effective, and do not protect against transmission, meaning herd immunity is impossible with toxoid vaccines

<u>VLPs:</u>

- Virus-like particle vaccines can almost be considered a type of protein vaccine, as they utilize the fact that for some pathogens, when putting together specific proteins that are derived from the pathogen, create a specific structure that imitate an essential part of the virus
- These are considered better for creating an immune response than protein vaccines, and HPV vaccines are an example of this

<u>Polysaccharide/Polysaccharide Conjugate:</u>

- The original polysaccharide vaccines were an attempt to isolate the capsules of certain bacteria that had specific polysaccharides on them to allow for the immune system to recognize and fight them off
- However, they weren't very good, as they offered short-term protection with the added drawback of decreasing protection with additional shots
- After studies in the early 1900s, it was found that if the isolated polysaccharides were combined with a carrier protein (i.e. polysaccharide conjugate), the immune response was improved against the pathogen; in fact, herd immunity is achievable with these vaccines with their effective antibody production

React:

Surprisingly, none of the sources were too lofty or hard to understand, as each one explained the topic at about the level that I currently learn at in biology and chemistry. This allowed me to come away with an even greater understanding of the vaccine types and broaden upon what I learned from the senior project. The main article that gave the most information and the broadest overview of each of the vaccine types opened up new pathways for further research, such as continuing my interest in learning more about herd immunity and the overall interdependence between society and vaccinations (especially with the fact that some healthcare providers are not very informed themselves about vaccines), what the future of vaccines looks like (or what may even be considered the current state of vaccines with the pandemic), and the workings of the immune system. Although I went ahead and did additional research on the immune system with one of the auxiliary sources (which was done to better understand the main source), I feel as if I have oversimplified the immune system and narrowed in on the parts that pertain only to vaccines. In fact, having more of a greater understanding of immunobiology could enrich my understanding of the process from vaccine -> antibody. However, this interest in the immune system points towards a consequential realization I have learned about myself in the process of researching the question at hand, and that is that I simply enjoy learning about the inner mechanisms of simply anything. From my enjoyment of "How It's Made" on YouTube to my prior desire to include psychology (basically understanding why we do the things we do) in my I-Search, I never realized that and put it all together until now. With this in mind, I now know what I truly enjoy learning about, which should make my next years of education easier when it comes to self-led projects, such as the senior project.

Sources:

Vetter, V., Denizer, G., Friedland, L. R., Krishnan, J., & Shapiro, M. (2017). Understanding modern-day vaccines: what you need to know. *Annals of Medicine*, *50*(2), 110-120. https://www.tandfonline.com/doi/full/10.1080/07853890.2017.1407035

Janeway, C. A., Jr., Travers, P., Walport, M., & Shlomchik, M. (2001). The Humoral Immune Response. *Immunobiology: The Immune System in Health and Disease* (5th ed.). Garland Science. https://www.ncbi.nlm.nih.gov/books/NBK10752/

Pöri, P. (2018). *Development of Vaccines* [PDF file]. Theseus. https://www.theseus.fi/handle/10024/143068

Research Post/Question 3: **What is the interdependence between vaccines and the public? (Herd Immunity & Vaccine Hesitancy) (Documentary)**

About:

All three of these video sources discuss the relationship of vaccines with the general public, whether it be focusing solely on herd immunity, vaccine hesitancy, or both topics at the same time. In "The Vaccine War," both viewpoints of pro-vaxxers and anti-vaxxers are discussed in actual interviews with representatives of both sides, discussing various contentious issues in the vaccine debate, such as autism, the heavy early vaccination schedule put on children, and the effects of anti-vaxxers' vaccine hesitancy on the possibility of herd immunity for those who need it most. In addition to the interviews, specific examples of scientific studies and online forum discussions were also shown to demonstrate each side's opinion. Romina Libster's TED Talk discusses the generalities of herd immunity that have already been discussed or known from prior knowledge while giving specific examples and anecdotes of herd immunity in practice (or where it could have been useful). On the other hand, Heidi Larson's TED Talk describes her opinion as to why vaccine hesitancy exists; she details that the diffusion of rumors about vaccines can solely be attributed to how the scientific community cannot adequately address and speak to the public about how these rumors are false. These were found through my prior knowledge of *Frontline*, made by PBS, and TED Talks being reliable sources of information while being somewhat interactive at the same time.

Point:

Prior Knowledge:

- Vaccine hesitancy appears to be generally caused by misconceptions of various individuals, ranging from the belief that vaccines cause autism, concerns about their safety, and questions about the contents with vaccines
- Herd immunity is established once a large majority of the population develops immunity against a certain pathogen (and therefore disease), allowing protection for those who cannot safely receive a vaccine; one of the safer ways in which herd immunity can be established is with vaccines as opposed to natural infection
- Although not explicitly mentioned in any prior source, it appears as if vaccines depend on the public's trust to work effectively (through herd immunity), and the public depends on vaccines to be safe and effective in keeping them protected against disease
    - However, vaccine hesitancy undermines this relationship between vaccines and the public, as with some people choosing not to receive a vaccine on time or completely refuse to receive one, diseases previously eliminated by vaccines reestablish themselves in communities, thus unraveling the whole system of vaccines depending on the public and vice versa

Knowledge Obtained:

"The Vaccine War:"

<u>On the Side of Pro-Vaxxers and Health Professionals:</u>

- Professionals counter the concerns about the vaccine schedule by arguing that vaccines comprise a very, very minute portion of the antigens a child is exposed to; there's not much substance given in each vaccine because there's no need for it, therefore indicating there should not be any worry about how many vaccines a child is given within a relatively short period of time

- Professionals do note that there can be side effects related to vaccines, even noting ones that possibly aren't caused by the vaccine themself, but the vast majority of vaccinations delivered to people do not cause anything adverse
    - There are also people who may be unknowingly allergic to a component of vaccines
    - They argue that the benefits of vaccines largely outweigh the risks of vaccines
- Many medical professionals, such as Paul Offit and Melinda Wharton, believe in the efficacy of vaccines and their true benefit, listing off diseases that have been eradicated and controlled by vaccines, such as polio, hepatitis B, and diphtheria
- Vaccines have a cost benefit in preventing public health officials from having to perform contact tracing, which is why public health officials appeared to dislike how measles, apparently the most infectious pathogen, began to spread
- Most outbreaks of infectious diseases begin in under-vaccinated areas after the source comes from overseas
- Pro-vaccine parents are concerned for the safety and wellbeing of other children as well in choosing to vaccinate their kids
- One of the ways in which vaccine hesitancy could be reduced is through using a bit of <u>pathos</u> and showing the imagery of the diseases that have been eliminated by vaccines - with this, parents probably won't think twice about vaccinating their children against such a horrible disease
- Doctors are concerned about those children, who by choice of their parents, are not vaccinated against preventable but deadly diseases and also about those children who already have autism, as resources are being eaten up by what they believe to be an already unfounded theory (vaccines cause autism)
- In response to the personal takes on health made by anti-vaxxers, doctors bring up the point of herd immunity and how that that can help protect the whole community - if not a majority of the population is vaccinated, people such as those too young/old and too sick who cannot receive a vaccine are the first ones to be affected
    - Additionally, professionals argue that parent choice is limited as well since there is a reasonable limit to the extent at which parents can act, as the reverse argument can be made that by not vaccinating, parents are knowingly putting their children at risk of death, which is not allowed

<u>On The Side of Anti-Vaxxers:</u>

- Additional long-term symptom believed to be caused by vaccines is ADHD (in addition to autism)
- As soon as a baby is born, they are scheduled to receive a multitude of vaccines within the first 6 years of their life to fight against 14 diseases (*possibly another cause of vaccine hesitancy is just the sheer amount of vaccines necessary - seems like a lot, at least on paper*)
    - Apparently more vaccines are begin given today than were in the late-1900s
- Personal belief exemptions are how some parents are allowed to go without vaccinating their kids, which then ultimately has a negative effect on those who are not able to vaccinate due to a preexisting condition
    - Another personal belief that leads to vaccine hesitancy is that getting sick naturally is better than getting vaccinated against the disease - argument is is that humans have gotten sick naturally before the advent of vaccinations, so there must not be anything wrong with natural infection
- *Perhaps another reason for vaccine hesitancy is the fact that* all of the major bodies of health and also pharmaceutical companies are unilateral in saying that vaccines are ultimately beneficial; *there is no personal spokesperson to court the anti-vaxxers to believe in vaccinations, causing skepticism*

    - Anti-vaxxers cite Paul Offit as an example of why they distrust the higher sources of authority when it comes to vaccines - they're just in it for the profit, not for the benefit of humans
- Another reason is complacency - because of vaccines' efficacy, the disease they prevent have not been around in a major way to inspire people to get the vaccine to fight against it
    - People do not believe in vaccinating against a certain disease if it is not rampantly spreading (or simply not presently in their faces), even if the reason why the pathogen is not widespread is due to vaccinations
- The various ingredients and contents of vaccines, besides the antigens within, are also a point of contention for anti-vaxxers - they cite aluminum (*the most commonly used adjuvant, which increases efficacy of vaccines*), mercury (thimerosal), and other substances as concerning ingredients
- When confronted by the possibility that they hurt other children (i.e. the immunocompromised) by their choice of not vaccinating their children (which they maintain because of their logic that if vaccines work, then it shouldn't matter), anti-vaxxers just sort of dismiss it and go back to one of their foundational beliefs that health and matters when it comes to personal health are exactly that - personal, not public/communal

<u>Vaccines and Autism:</u>

- The link between vaccines and autism is one of the most dominant reasons as to why vaccine hesitancy occurs
- According to this documentary, the origins of a link between vaccines and autism started with the advocacies of various celebrities, who found sources that agreed with their suspicions after their own children got autism after vaccines, such as Generation Rescue, an organization set up by a businessman who seeks to organize parents who had thoughts that vaccines led to autism
- Their main argument to support the belief that vaccines lead to autism is that the amount of vaccines administered to children has gone up in recent years at the same as autism rates/complaints of autism in children after vaccines have also skyrocketed
    - As part of the belief that vaccines cause autism, one of the supporting pieces of evidence they hold is that vaccines can also cause brain injury in some people
- The source and the "scientific backbone" of this theory is Andrew Wakefield's scientific journal that originally only noticed gastrointestinal problems after vaccines but then also noticed signs of autism developing in those same cases as well after the vaccine
    - He believed that, aligning with the gastrointestinal problems, the children's intestines leaked out, damaging the brain as a result of the vaccine administration
    - While this does sound damaging to vaccines at face value, Wakefield himself stressed how this only appeared in a very minute set of children, suggesting that this should not be overblown and that vaccines do still provide some benefit
    - His paper was retracted out of the Lancet after the studies below were published, as it did not show proper means of replication and had some possible cherry picking/conflict of interest concerns within its chosen children to study, leading to the demise of Wakefield's reputation
        - However, he still is supported by anti-vaxxers
- In response to the studies below, anti-vaxxers maintain that there should be additional studies, such as those of other vaccines, done to rule out vaccines causing autism, as no alternative for the cause was suggested by those studies

    - The response made by scientists to this is that a) it's unethical, as one cannot in good faith give a placebo instead of a vaccine to someone who doesn't know about it and b) the target keeps shifting for anti-vaxxers, which apparently is a sign of fake science

Professionals' Response to "Vaccines -> Autism:"

- In 2010, large movement of anti-vaxxers began to form, causing a debate that began to resurge as a result a measles outbreak in Disneyland, which was a previously controlled disease by vaccines
    - This movement continued to grow in the time afterwards, leading to the measles outbreak that spread across the country from Disneyland
- Experts argue against vaccines causing autism, as they note how it may just be a coincidence that symptoms of autism develop at around the same time that children are administered a whole variety of vaccines
    - Basically, this means that correlation between the time at which vaccines are distributed and when autism symptoms develop does not mean causation (does not mean that vaccines cause autism)
- In regards to the concerns over vaccine ingredients (e.g. mercury) causing autism, an autism expert from the episode states that mercury poisoning and autism are two separately different conditions
- In addition, the Danish study mentioned below also looked at thimerosal in vaccines and autism rates, as only the pertussis vaccine in Denmark contained thimerosal for a brief period of time, and it too found no significant difference between non-thimerosal-containing vaccines and thimerosal-containing vaccines causing autism
- Before any studies could be finished on if there truly was a linkage between thimerosal and autism, the FDA pulled the plug on it being in vaccines, basically confirming the notions of the multitudes of parents
- One of the ways anti-vaxxers continue their mistrust of vaccines is by continually stating that studies first need to be done before the vaccines can regain their trust
- In a Danish study, which was emphasized to be trustworthy by way of their ease of access of public health data, including vaccine administration dates and autism cases of children, there was no evidence found of there being any difference in non-vaccinated children vs. vaccinated children in terms of autism rates
    - This study, along with a whole slew of other studies, corroborate how vaccines do not cause autism
    - This finding is also best exemplified in Japan, where the vaccine schedule was changed to separate the Measles, Mumps, and Rubella vaccine (the primary target of anti-vaxxers) into three separate vaccines, as autism rates in fact <u>increased</u> after the schedule change
- Further undermining the validity of the claim that vaccines cause autism, a federal court ruled against anti-vaxxers who had filed lawsuits claiming damages related to vaccines supposedly causing autism, citing that there was no evidence to suggest the plaintiffs were right

To the Future:

- It doesn't seem like the "vaccine war" will end anytime soon due to the advent of the Internet
    - The ease with which theories and ideas can be shared without repercussions causes some of those theories to gain popularity before even any context can be placed on them, such as in the case of the Redskins cheerleader saying that she had an adverse reaction to the flu vaccine

- According to professionals, they believe there is too much trust by the public put in any source of information found in the Internet (e.g. YouTube video) as opposed to verified sources such as health organizations
- For anti-vaxxers, the Internet is seen as a boon to their cause - it allows them to freely distribute their ideas and overall, allows for more free discussion, which leads to the challenging of medical science by the public
- While the pro-vaxxers pushed (at the time of this *Frontline* episode) for new legislation to get rid of the personal belief exemptions that prevented herd immunity from establishing itself at, for example, schools, the anti-vaxxers went to the Internet to push back against this legislation and sort of "rally the troops" to fight against the legislation from being passed, citing, once again, their belief in the privacy of health
- Politics has become increasingly as a part of the "vaccine war," as sides are being chosen based on the question of freedom and parent choice/say in the matter of vaccines

Romina Libster (Herd Immunity):

- The percentage of people who need to receive a vaccine for herd immunity to be established is called the threshold
- As a result of Wakefield's article, the threshold was disestablished, leading to measles outbreaks across the world
- Vaccines are a personal duty - they are necessary to protect oneself from disease (it would be negligent to not get one otherwise, whether the choice is made by the parent - child is being put at risk - or by the person themselves), but they have an impact on other people unlike other medicines
- *Basically a reaffirmation of Frontline documentary - what herd immunity is, how it's established, Wakefield's article*

Heidi Larson (Vaccine Hesitancy):

- Rumors are caused by a mistrust of vaccines held by local leaders (not necessarily individuals/parents worried about their children), such as those rumors held about the polio vaccine (that it was used for spying by the CIA, a contraceptive, etc.)
    - Politics became involved into the scientific community since those rumors developed in Nigeria after 9/11 - Nigerian leaders believed that the US was out to get them
- Larson established the Vaccine Confidence Project in 2010 after witnessing the effects of rumors on vaccine efficacy, grouping together a whole range of experts to study the prior effects of vaccine hesitancy caused by rumors
    - As part of their work, they developed the vaccine confidence survey as a means to gauge specific populations as to whether a vaccine will work in a specific community
    - They also study simply the various ways in which rumors spread through the Internet amongst social groups
- Apparently, according to this person, Europe is the most skeptical region when it comes to vaccine hesitancy and rumors, and France was the most skeptical country in Europe
    - There was a strong correlation between populist voters and vaccine skepticism that was found when trying to dig into the reason why this was so, reaffirming how science has become intertwined with political gain and has become part of the tribalism within politics
- Causes of Vaccine Hesitancy:

    - Vaccines are pushed by governments, as requirements of having a certain vaccine are present at the different stages of life
    - Vaccines are made by pharmaceutical companies, in which a lot of mistrust is held
    - Within those pharmaceutical companies, there are the actual “big wig” scientists that create the vaccines, who may possibly see themselves above the general public and also talk a foreign language in relation to the rest of the public
    - The Internet is a breeding ground for misinformation and rumors to get exponentially larger
    - Vaccines are worldwide and affect every single person, making them a great target as a means of disrupting the status quo and to cause chaos
- The problem that causes vaccine hesitancy to snowball is that pro-vaxxers are too quick to judge a person as being a part of an anti-vaxxer group if they raise any questions, even if they simply are just curious and not necessarily completely anti-vaccine
    - As a result, those who are “in the middle” and undecided as to whether or not they should get a specific vaccine are discouraged by those who encourage the vaccines, causing them to be courted by the side of anti-vaxxers
- There simply needs to be more listening and much more responsive, effective communication done between health professionals and those who simply just have a few questions about vaccines, emphasizing the importance of effective scientific/medical information
    - This could be done through volunteerism, better education, and advocacy groups on the side of vaccines
    - Ethan Lindenberg is an exemplar of effective communication, as he emphasized how there is also misinformation spreading that says that people who simply have questions about the safety of vaccines are automatically on the side of evil when in actuality they were just caring parents
- The problem lies not in the information (or lack thereof) that is currently available to the public to disprove rumors, but in how that information is communicated (or as she says it, a “relationship problem”)

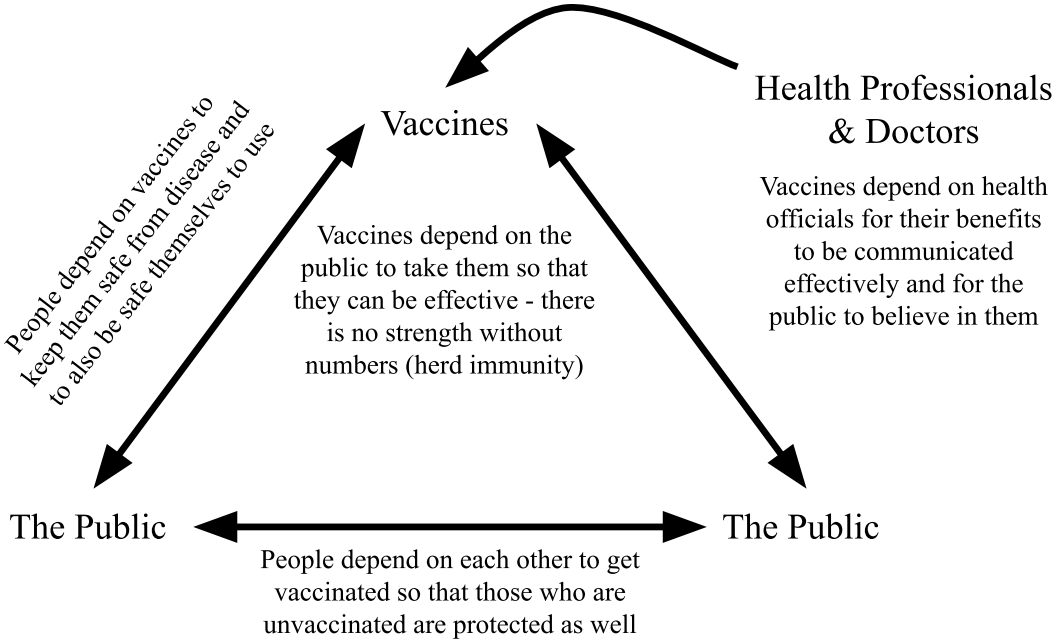
React:

There were so many takeaways that I took from these audiovisual sources, but I first have to start off with the fact that I enjoyed them so much. It may be due to the extreme contrast between coming from Google Scholar’s dense articles and these relatively easy-to-understand videos, but it was very refreshing to simply sit back, casually watch, and obtain knowledge as opposed to having to actively read. To start, there were, of course, new viewpoints and opinions that I never knew existed or never knew were held by the sides of pro-vaxxers and anti-vaxxers, such as vaccine complacency. However, this is more so a surface-level understanding, as there were two more realizations I came to during this part of my research. The first of them is that the interdependence of vaccines and the public is not as linear as I thought it once was. I simply thought that vaccines depend on the public and vice versa, but after the *Frontline* episode in particular, I realized that it is a bit more complex than that, as there is dependence within the public. People rely on other people to be vaccinated so that herd immunity can occur for those that go without the vaccine, and this dependence is probably more significant than that of people on vaccines.

In regards to the future, the last takeaway from all of this relates to another possible research question, which is how science can effectively communicate with the public. Vaccines are a case study into how science has

faltered in communicating its findings and benefits, as vaccines do have their own set of adherent doubters, similar to how global warming has its own non-believers. Further research could be done into how to improve science's means of communication, aligning with my interest in psychology and the aforementioned idea of doing some sort of advocacy campaign about my selected senior project topic. In fact, my original topic before this was going to be something related to psychology in medicine, and I was going to start off with Alex C.'s senior project on emotional intelligence in the medical field as my first APR. My interest in psychology and medicine stems from how I believe the scientific community's language to be too complex for the general public to understand, causing them to not bother; for example, complex graphs and research illustrating the effects of global warming do not speak heavily to the public. Going along with this, from specifically Larson's TED Talk, the different advocacy groups and organizations, such as the Vaccine Confidence Project that she is a part of, that have a stake in the "vaccine war" was also opened up as a possibility as a stimulus for further research. It would be an authentic, direct way of getting to know the various viewpoints and taking them all into consideration, and again, some form of advocacy would be a great senior project idea.

Below is a visual summary of this section:



Sources:

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Larson, H. (2020, March). *Why rumors about vaccines spread - and how to rebuild trust* [Video]. TED. https://www.ted.com/talks/heidi_larson_why_rumors_about_vaccines_spread_and_how_to_rebuild_trust

Palfreman, J. (Writer & Director), & McMahon, K. (Director). (2010, April 27). The Vaccine War. (Season 2010, Episode 16). [Tv series episode]. In D. Fanning (Executive Producer), *Frontline*. WGBH Educational Foundation. (https://www.pbs.org/wgbh/frontline/film/vaccines/)

Research Post/Question 4: **In the context of the COVID-19 pandemic, what does the future of vaccines currently look like? (DNA/mRNA Vaccines, Vectored Vaccines, & Other Vaccine Innovations) (Resource Synthesis)**

About:

All of the following articles discuss the vaccine innovations that were previously mentioned in prior research. The COVID-19 pandemic and its need of a novel vaccine in a short amount of time caused the innovations to be prioritized because of their ability to either be developed in a short amount of time or reduce vaccine hesitancy in a crucial time. In fact, the initial interest as a whole for vaccines stemmed for receiving the Pfizer COVID-19 pandemic and getting the short end of the stick when it comes to side effects, so I especially wanted to narrow in on what exactly were the novel vaccines; with the background research I have already done, I found myself finally in a place ready enough to truly understand what makes the COVID-19 vaccines unique. All of the sources were found through Google searching various terms related to the future of vaccines, so there was no concern over whether the articles would be too lofty to understand. The reason as to why each one was chosen is for their unique perspective they offer in relation to the vaccines and the pandemic.

The resource page and video made by Gavi, an organization that works to provide equitable vaccine access, discuss the various vaccine types currently either available or being worked on by various companies for use in the pandemic. Each vaccine type is discussed at length for its process of manufacturing, advantages, and disadvantages; of the ones Gavi describes, the types of particular interest were the nucleic acid and vectored vaccines. Gavi's article made up a majority of my research in terms of its foundation in describing the new vaccine types in the pandemic.

Hendaus' and Jomha's article, written by two authors who have extensive medical knowledge working at schools of medicine, discuss various facts relating to specifically the mRNA vaccines being used in the pandemic. It was written for the purpose of dissuading any misconceptions and vaccine hesitancy held by the general public, and in regards to its utility of adding on additional information onto Gavi's article, it discusses in more detail the process of mRNA making its way from initial injection into the cell to express the spike protein, which is the antigen chosen against the pathogen. While somewhat unrelated to the research question at hand, the article also discusses the trials that every vaccine, including the mRNA vaccines for the pandemic, goes through.

Katella's article, published on the trustworthy source of YaleMedicine, discusses the vaccines currently in use or close to being in use for the COVID-19 pandemic by company brand (i.e. Pfizer, etc. as opposed to by vaccine type (i.e. subunit, mRNA, etc.). While it did provide some clarity on the background knowledge I lacked about what vaccine type each company developed, it really only provided the association between which company is developing what vaccine type (e.g. the Pfizer-BioNTech vaccine is an mRNA vaccine). Nothing of substance or of use was provided past that.

Dolgin's article discusses the timeline of RNA vaccine technology from before the pandemic, during the pandemic, and what the technology may look like past the pandemic. In this, some topics that she details

include using saRNA, a different type of mRNA, for a better immune response, the setbacks of RNA vaccines in the eyes of the pharmaceutical companies before the pandemic, and vaccine patches.

Mandal's article gives a background on vaccine administration and what the prior methods were before discussing the newer vaccine delivery techniques currently being used. The article does not offer a lot of depth to the vaccine delivery innovations past merely listing them, which is what the intent was when attempting to research the vaccine delivery methods mentioned in prior articles, but it did give enough to provide a launching point for future research. However, one of the vaccines currently in use for the COVID-19 pandemic are currently utilizing a new form of vaccine delivery, so I did not consider a big point of emphasis that really needed to be outlined in detail.

Point:

Prior Knowledge:

- The current COVID-19 vaccines are of a new type called mRNA, where the instructions to make some type of antigen (typically a protein) are instead delivered as the vaccine
- The mRNA is then brought to a cell within the body and translated for the instructions to make the protein, allowing the cell to express the antigen
- This then causes the appropriate immune response with antibodies
    - I'm not sure which brands of the COVID-19 vaccines are mRNA vaccines, or if there are even any difference between the different brands (meaning I'm not sure if they are all just mRNA), but I do know Pfizer, the one I received, is mRNA
- Vectored vaccines skip the delivery step of mRNA vaccines and just deliver a non-infectious virus with the antigen of a specific pathogen already expressed
- There are also additional innovations currently being investigated, such as new means of delivering vaccines other than through injection with a needle

Knowledge Obtained:

General Information as It Relates to the COVID-19 Pandemic:

- There are at least 63 different vaccines being developed for the COVID-19 pandemic, each by different companies; they are of 4 types: whole virus, protein subunit, nucleic acid (DNA/RNA), and vector
- The antigen being used by all of the types of potential COVID-19 vaccines (whether they deliver it themselves or if they instruct a human cell to make it) is the spike protein found on the outside of the virus
- **S**pike **Protein** of coronaviruses help the coronavirus get through the plasma membrane to infect the cell, illustrating why the S protein is used as the antigen against the pathogen
    - "Whole virus" typically just means inactivated vaccines in the context of COVID-19 vaccines (*they induce an immune response by introducing a weakened form of the virus that still has the antigen but is unable to cause disease*)
        - Unrelated, but live attenuated vaccines can also be for bacterial pathogens, such as tuberculosis
        - Inactivated vaccines considered safer than live attenuated vaccines because genetic material destroyed in inactivated vaccines, therefore less risk of disease is maintained
    - Protein subunit COVID-19 vaccines just use the spike protein as the contents of the vaccine and deliver those; of course, they won't be able to cause disease, but they may not be as effective

        - Require adjuvants (*a compound delivered with the rest of the vaccine's antigens to stimulate more of an immune response*) and booster shots
            - The Novavax vaccine, currently not in use in the U.S., is a protein subunit vaccines that doesn require an adjuvant
    - Both vectored and mRNA vaccines deliver the mRNA genetic material/instructions for the cell to express it; they just differ in their means of transportation
        - Vector COVID-19 vaccines use an adenovirus (cannot cause disease) to deliver the mRNA genetic instructions to the cell
            - The Johnson & Johnson vaccine is a vectored vaccine currently in use against the pandemic (one shot vaccine and can be stored at more regular refrigeration temperatures in comparison to Pfizer & Moderna)
            - AstraZeneca's vaccine is also a vectored vaccine but is not in use in the U.S.
        - mRNA COVID-19 vaccines use direct transmission ("gene gun") or have the mRNA attach to a molecule that delivers it to the cell
            - The Pfizer/BioNTech and Moderna vaccines are mRNA vaccines currently used in use against the pandemic
                - Moderna's vaccine differs from Pfizer in that it may be less effective and can be stored in temperatures relatively standard for the common fridge
- The reason for the need of the newer forms of vaccines such as the nucleic acid vaccines is because the established forms of vaccines take too long to produce in the context of a global, rapidly-evolving pandemic
- The reason for the two doses associated with some pandemic vaccines is because the first one causes the initial exposure to the S protein and the second one is what causes the immunological memory to really stick

How Vaccines are Tested (while appearing somewhat unrelated, would be important to note, especially considering the novelty of the vaccines of the "future"):

- Preclinical Testing: trials done on animals to ensure purpose is appropriately fulfilled (i.e. does it work to create the right antigens?)
- Phase 1 Safety Trials: trials done on small, concentrated set of humans to ensure safety and that purpose is appropriately fulfilled
- Phase 2 Expanded Trials: same trials as the prior stage but done with more people (~several hundred)
- Phase 3 Efficacy Trials: trials done to prove safety, efficacy, and proper purpose fulfilled with very large group of volunteering individuals (~tens of thousands); large data set allows for record of side effects
- Approval: officials read over results of trials to determine whether vaccine should be approved or not
- Paused: whenever officials notice something odd during the trials that needs to be investigated further, they reserve the right to "pause" production and the trials from being conducted at any stage
    - *All of the above demonstrates the rigorous testing vaccines are put through before being ever released to the public*
    - mRNA vaccines have gone through Phase 2 at the very least at the time of this being written during the COVID-19 pandemic - production was expedited, explaining why the vaccines were so quick to be released, but safety trials were not expedited

Nucleic Acid:

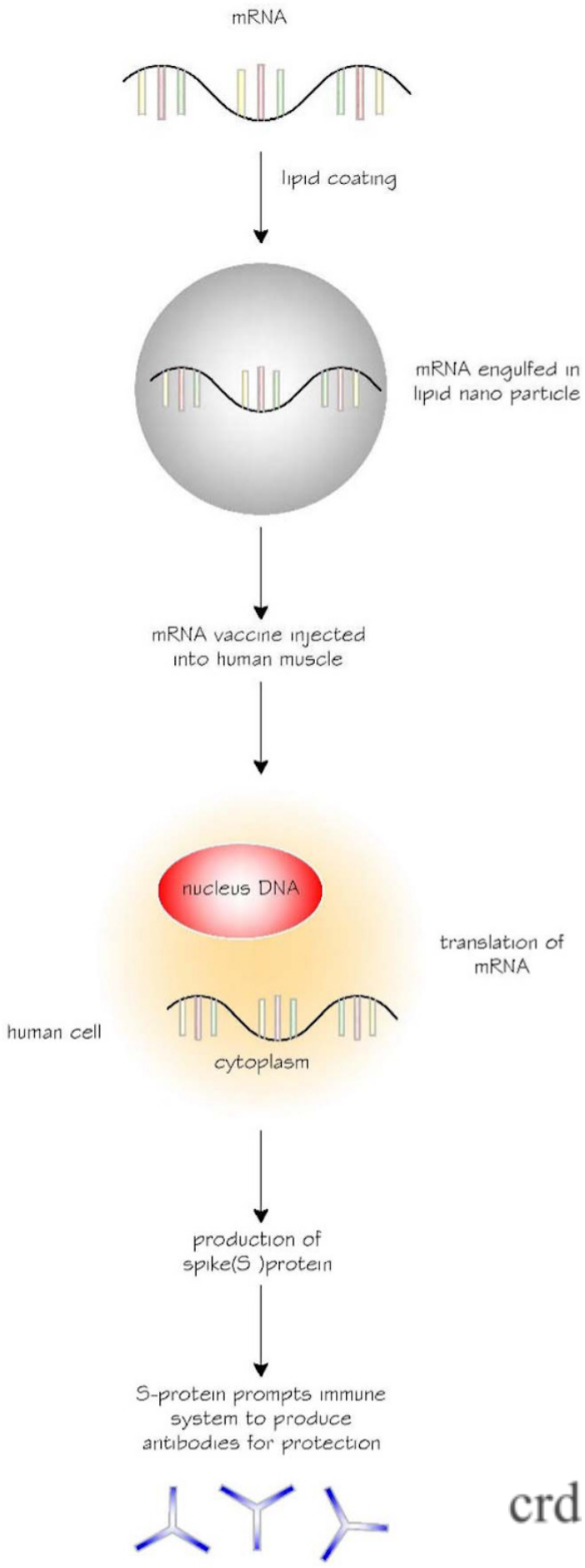
- While they're relatively easy and fast to manufacture (*as indicated by the short period of time in which the COVID-19 vaccines were developed*), they may require booster shots in the future
    - This is due to the fact that once the genome of a pathogen is sequenced (*once all of the possible alleles that can exist as part of the pathogen's genetic material are known*), all of the work is practically done at that point - just need to make a copy of the specific genome that codes for the antibody at that point
- Can also be more cost-effective than the established vaccines because they can be made by the same equipment in the same place

DNA:

- DNA and mRNA vaccines are still in the experimental stage of their development (none have official approval - *only Emergency Use Authorizations*), as they haven't gone through the rigorous testing that other types of vaccines have been through
    - While mRNA vaccines are still being experimented with, the technology has been around for a little while already (it's not as novel as it seems); the only reason why they appear to still be in the experimental stage is that there was a lack of interest in them until just recently with the pandemic
        - The setback that declined the initial interest in mRNA technology was because of the problem of the lipid coating being too toxic at first
            - Once the breakthrough for the lipid nanoparticle, the pharmaceutical companies were still hesitant at first due to regulation - only a few companies took it on, but nothing of substance was approved before the pandemic
- Side effects of nucleic acid vaccines are attributed to how they're hard to purify completely and the lipid nanoparticle
- DNA vaccines have been approved for animals, such as ones for horses
- The sequence of DNA from the pathogen (the specific sequence that codes for the antigen) is put into a bacterial plasmid (*circular DNA that is separate from the single circular chromosome of prokaryotes; typically used for keeping adaptations that help the bacteria survive, but in this scenario, the property of plasmids that is utilized for DNA vaccines is that they can replicate and exist outside of the single circular chromosome*)
    - Plasmids have already been used for genetic engineering purposes
- The plasmids, now with the antigenic DNA, are now the contents of the vaccine that are injected into the muscles of humans
    - The problem now lies with how to get the DNA plasmid into human cells so that it can be expressed (*problem would logically exist, as the reason why mRNA exists in regular protein synthesis is because DNA itself is too large to escape the nucleus to act as a direct player at the ribosome*)
        - Current solutions include electroporation, where electrical currents open up holes through which DNA can pass through the plasma membrane; "gene guns," where helium gas is used to push the DNA through; and nanoparticles (who have the plasmid either attached to their outside or within them) that can fuse with the plasma membrane
- Enzymes (*such as, what I presume to be, DNA restriction enzymes*) help with putting the pathogenic DNA into the plasmid before the bacteria in which they are located are allowed to reproduce and replicate the plasmid (eventually the plasmid is isolated)

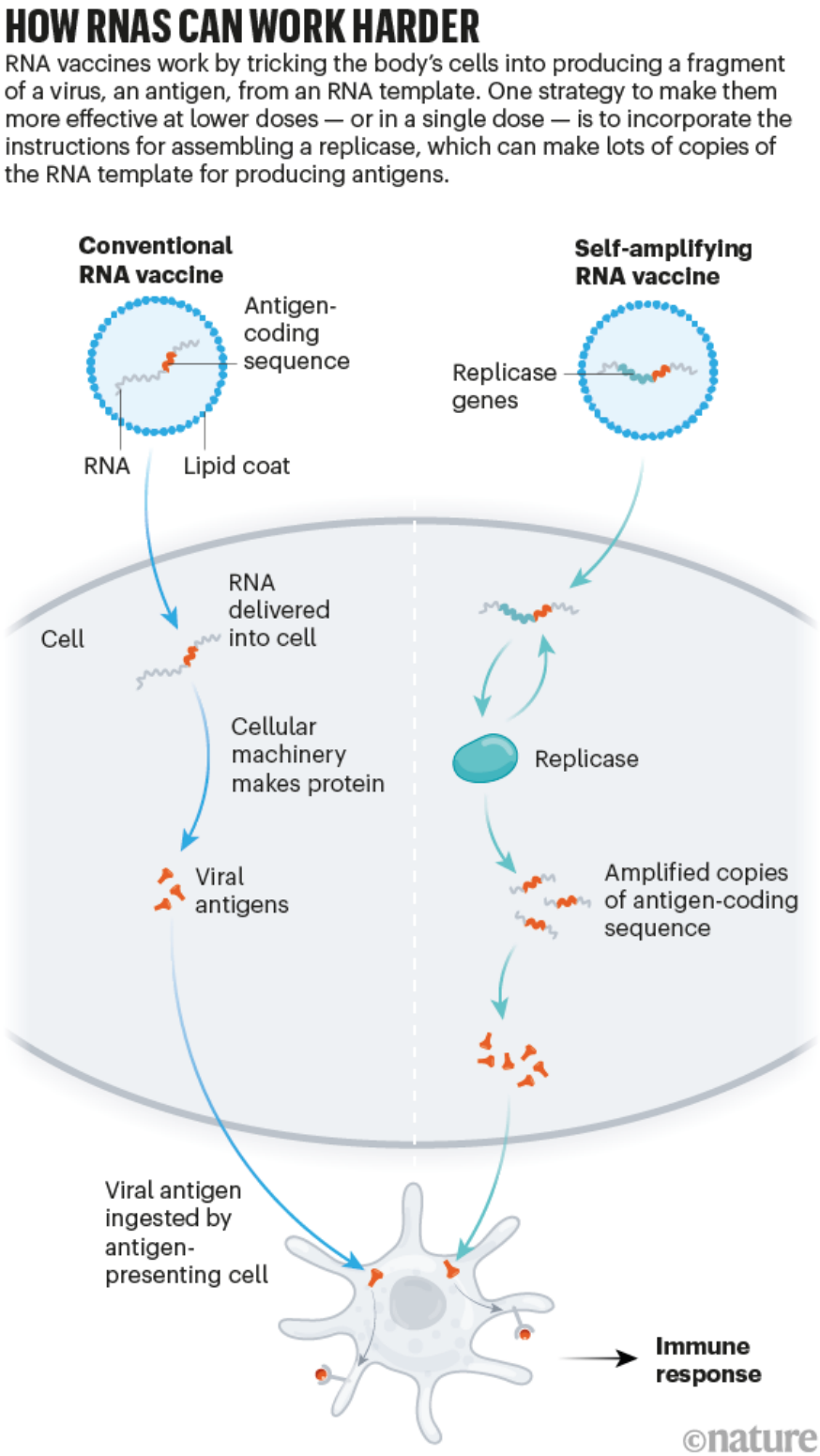
mRNA:

- Unrelated, but mRNA has also been used in the field of oncology to fight off some cancers
- No risk of interfering with existing genetic material, as *mRNA is meant to be transferable and perishable copy of DNA*
- The basic premise of an mRNA vaccine is that mRNA, a copy of the specific DNA sequence that codes for the antigen of the particular pathogen to be expressed, is delivered a human cell, where the mRNA is read for its instructions on how to express the antigen (*has to be a protein, as mRNA is only a part of the process of protein synthesis*)
    - *The instructions delivered by mRNA are brought to the site of protein synthesis in the cell, ribosomes, where the protein is made and then delivered to the outside of the cell*, now making it an antigen that antibodies can bind and recognize to
- The Details of Pathogenic mRNA once Injected into a Human:
    - The nanoparticle in which the mRNA is contained travels to any cell; once it reaches the cell, the nanoparticle fuses with the plasma membrane (is allowed to because the nanoparticle is also made of lipids), releasing the mRNA into the cell
    - mRNA is then read for its instructions, and the antigen is created to be shown on the outside of the cell
    - mRNA then disintegrates after fulfilling its role as a perishable copy of DNA
        - No interaction between the mRNA and the nucleus is done, therefore genetic material is safe
- Visual diagram of above (while this pertains to specifically the COVID-19 vaccines, the S proteins can be substituted out for any antigen being expressed) is to the right
- mRNA can be the sole contents of the vaccine or it can be delivered with the nanoparticle method mentioned under “DNA” - Pfizer’s COVID-19 vaccine



uses nanoparticles - or any other method used for DNA vaccines

- mRNA vaccines faster to produce than DNA vaccines because they can be made without the usage of living bacteria
- They're also easily adaptable against mutations because it just requires using a different sequence of mRNA, which is easy to obtain once the genome is sequenced
- These require cold temperatures so that they do not decay quickly
    - For example, the Pfizer-BioNTech requires temperatures of -94°F so that it can be stored properly, which can be difficult for administrators to maintain
    - The reason for the cold temperatures is because of the nature of the lipid nanoparticle in which the mRNA is contained - needs to be maintained in cold temperatures
- The second-dose nature of most mRNA vaccines doesn't help with compliance in getting the full immunity of the vaccine
- Other possibilities with mRNA past the pandemic are being explored, such as having a flu vaccine that doesn't require yearly renewal and an HIV vaccine - mRNA vaccines allow for the possibility of having multiple instructions for different antigens within the same dose



saRNA:

- mRNA vaccines can also be saRNA (self-amplifying RNA) - may be better than regular RNA vaccines because of their ability to be more like a natural infection; the reason for the name is because of their ability to self-replicate (include the gene that expresses the enzyme for replication), which

allows for less dosage than mRNA vaccines, but are harder to manufacture

- Visual Diagram of Differences:

Vectored:

- Contrary to my prior understanding, vectored vaccines do not already have the antigen expressed by the virus that carries the antigen to provoke an immune response; instead, they too have genetic material like the nucleic acid vaccines
- The vector, a modified, non-virulent virus, carries genetic material of the pathogen that expresses the antigen of the pathogen to cause an immune response
    - The reason why this is its own distinct category from nucleic acid vaccines despite delivering the same main component is because of the specificity of the utilization of the vector as the delivery method - because it works as a virus, it simulates the actual process of an real, natural infection, causing the immune response to be stronger than those of nucleic acid vaccines
- Unlike nucleic acid vaccines, vectored vaccines are already established, as one example of them would be a vaccine against Ebola
- Vectored vaccines use the basic principles of how viruses function to deliver the genetic material - viruses are nonliving particles that require a host cell to reproduce, so they invade any cell they can and cause the cell to express their genetic material (instead of the cell's regular DNA), which creates new viruses and killing off the host cell in the process
    - However, with the vector being a modified virus, the genetic material of the viruses that comprise the vaccine express that of the antigen only (it replaced the original DNA of the viruses), causing no chance of disease
- Adenoviruses, measles virus, and vaccinia virus have been used as vectors for vectored vaccines
- Two types of vectored vaccines: those that still contain the gene that allows for reproduction of the virus, and those that do not contain the gene that allows for reproduction (only express antigen) - the latter is the type of the COVID-19 vaccines
    - In the case of those vectors that can reproduce, it still is harmless, as the newly replicated viruses only contain the same DNA as the original vector and travel to other cells to repeat of the process
- Ultimately, the same result as the nucleic acid vaccine results with vectored vaccines - antigens on the outside of infected cell are present and allow for immune response
- Some downsides of vectored vaccines are that they are tedious and costly to manufacture and that vectored vaccines will be less effective for people who have previously been exposed to the chosen vector

Delivery:

- The newer methods of delivery are being developed so that the public will be more willing to receive them due to the newer ease of delivering them on the part of the administrator
- For background knowledge, the already-existing/commonly-used methods of delivering vaccines are through the mouth (oral - PO), through the fatty layer right under the skin (subcutaneous), and into the muscle (intramuscular)
    - Intradermal (where the vaccine is only delivered in the most outer layer of skin) and intranasal (through the nose) vaccines also exist
- Needle-free vaccines include using jet injectors, a type of tool that uses high-pressure liquid to push its way through to the intended part of the skin (intradermal, subcutaneous, or intramuscular)

- Microneedle vaccines are being developed where the “site of injection” is distributed across a small rectangular surface through which the vaccine’s contents are distributed
- Vaccine patches being developed for the purpose of mRNA vaccines involve using microneedles that distribute the vaccine over time - could also help with side effects
- Nasal spray vaccines & liposome vaccines (phospholipid sac formed around water to deliver materials) are other methods in the work currently

React:

While there was no new, giant takeaway in particular that I was able to glean, I did gain an appreciation for the work the scientists at the various pharmaceutical companies have done or are in the process of doing all in an effort to fight against the pandemic. It’s amazing how in just the span of just over a year that they went from initial identification of the virus to having a vaccine that fights against that. Perhaps a topic for future research could be related to genetics and microbiology, as apparently the work of nucleic acid vaccines is mostly done once the genome of the pathogen is sequenced and known. Other topics for future research include more about vaccine delivery methods, as the source I used to understand more about them didn’t really hit the mark, and the regulatory aspect of vaccines (could be included with vaccine’s relationship with the public). However, this research mainly reinforced my prior overarching interests in microbiology, the immune system, and effective scientific communication with the public that I’ve developed over the course of my research into vaccines. My interest in microbiology was reinforced because of the way in which vectored vaccines work by simulating how regular viruses infect cells except in a modified way that brings safe immunity; my interest in the immune system was reinforced because of how the nucleic acid and vectored vaccines prompt the immune system to attack what was formerly its own cell; and my interest in proper scientific communication was reinforced because of how vaccine hesitancy, as evidenced by the purpose of Hendaus’ and Jomha’s journal entry, still exists in a time of a pandemic where vaccines and herd immunity are crucial.

Sources:

Hendaus, M. A., & Jomha, F. A. (2021). mRNA Vaccines for COVID-19: A Simple Explanation. *Qatar Medical Journal*, *2021*(1), 07. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7893482/

Katella, K. (2021, June 2). *Comparing the COVID-19 Vaccines: How Are They Different?* Yale Medicine. https://www.yalemedicine.org/news/covid-19-vaccine-comparison

Dolgin, E. (2021, January 12). *How COVID unlocked the power of RNA vaccines*. Nature. https://www.nature.com/articles/d41586-021-00019-w

Mandal, A. (2019, June 5). *Vaccine Delivery.* News Medical. https://www.news-medical.net/health/Vaccine-Delivery.aspx

Gavi. (n.d.). *There are four types of COVID-19 vaccines: here’s how they work*. Retrieved June 3, 2021, from https://www.gavi.org/vaccineswork/there-are-four-types-covid-19-vaccines-heres-how-they-work

Annotated Bibliography

Dolgin, E. (2021, January 12). *How COVID unlocked the power of RNA vaccines*. Nature. https://www.nature.com/articles/d41586-021-00019-w

In her article, Dolgin aims to discuss the prior history of mRNA vaccines before the COVID-19 pandemic and how the pandemic catalyzed an increased interest in mRNA vaccines, particularly by the pharmaceutical companies for its speed of development. The article also describes the generalities of mRNA vaccines, their current challenges, and the alternate saRNA vaccines. There appears to be no means of persuasion or bias towards one particular viewpoint, as it seeks to only describe RNA vaccines in the context of the COVID-19 pandemic, and Dolgin's sources are thoroughly cited at the end of the article. Within the text, any information given is supported by quotes from various experts and their opinions as opposed to the author's personal feelings towards the subject. Dolbin covers several topics that were helpful in adding on to prior research that only gave glancing mentions to specific subjects, such as what exactly were saRNA vaccines and explaining the reasons for the side effects associated with RNA vaccines and the reasons for the need of cold-temperature storage.

Gavi. (n.d.). *There are four types of COVID-19 vaccines: here's how they work*. Retrieved June 3, 2021, from https://www.gavi.org/vaccineswork/there-are-four-types-covid-19-vaccines-heres-how-they-work

Written in the context of the COVID-19 pandemic, this article and associated video made by Gavi, found through doing a Google search related to the COVID-19 vaccines, detail the various vaccine types in relation to those being developed for the pandemic, covering whole virus vaccines, which are a broader category of vaccines that include live attenuated and inactivated; protein subunit vaccines; nucleic acid vaccines, including DNA and mRNA vaccines; and vectored vaccines. The source covers each vaccine's development process, how each vaccine generally works, and the pros and cons of each type. While

citations are not listed in the same fashion as other sources in the bibliography, Gavi is an organization that has experience in advocating vaccines for individuals who cannot afford them, illustrating their reliability on the matter. No persuasive language or a particular viewpoint was apparent within the source, as it only aimed to inform the reader as to how each vaccine works; this includes any slant towards a particular vaccine type because both the advantages and disadvantages of each vaccine type were given, allowing the reader to perform their own analysis. Gavi gave a fundamental understanding of the future of vaccines as it stands currently in the COVID-19 pandemic, which turned out to be crucial in the process of developing further knowledge about mRNA and vectored vaccines.

Hendaus, M. A., & Jomha, F. A. (2021). mRNA Vaccines for COVID-19: A Simple Explanation. *Qatar Medical Journal*, *2021*(1), 07. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7893482/

In their entry in the *Qatar Medical Journal* found through Google, Hendaus and Jomha aim to refute much of the misinformation surrounding the COVID-19 mRNA vaccines in the hopes of dissuading vaccine hesitancy. To do this, they cover several topics relating to the vaccines, such as how they work in relation to the immune system, what exactly mRNA is, and the rigorous testing process that all vaccines are put through. While there is an agenda associated with publishing this article in favor of mRNA vaccines, the information given can be trusted on the basis of the authors' credentials; they work in pediatrics and pharmacology, demonstrating their expertise. Using trustworthy sources like the CDC and WHO for their research, Hendaus and Jomha also thoroughly cite their sources at the end and throughout the article. In regards to its utility, the authors further upon the general understanding gleaned from other sources about mRNA vaccines, describing in greater detail the journey of the mRNA from initial injection to its expression and the testing of the vaccines.

Janeway, C. A., Jr., Travers, P., Walport, M., & Shlomchik, M. (2001). The Humoral Immune Response.

Immunobiology: The Immune System in Health and Disease (5th ed.). Garland Science. https://www.ncbi.nlm.nih.gov/books/NBK10752/

Through *Immunobiology*, the authors aim to give any postsecondary student a general overview of the immune system and the related antibodies, antigens, and their workings; this particular chapter focuses in on how antibodies are first produced by the immune system against antigens and then narrows in on the three ways in which antibodies fend off any invading pathogens. The chapter was found through perusing the book itself, which was obtained through Google Scholar. Although the book itself is quite antiquated, being 20 years removed from this edition's initial publication, Janeway, Jr. and his coauthors have credentials stemming from prestigious universities and colleges in the field of healthcare, making this also one of the more reliable sources in this bibliography nonetheless. With their effective explanation of the humoral part of the immune system, the process of how vaccines prompt antibodies to be formed, leading to immunity, was given clarity in a way that did not provoke any confusion, illustrating its helpfulness. As a bonus, the immune system showed itself as another point of future enrichment that could further the understanding of vaccinology.

Katella, K. (2021, June 2). *Comparing the COVID-19 Vaccines: How Are They Different?* Yale Medicine. https://www.yalemedicine.org/news/covid-19-vaccine-comparison

Katella's article found through a Google search describes the COVID-19 vaccines by brand instead of their actual type like other sources found on the bibliography. In addition to the Pfizer-BioNTech, Moderna, and Johnson & Johnson vaccines, all of which are approved for use already in the U.S. Katella also covers the Oxford-AstraZeneca and Novavax vaccines, going over potential side effects, efficacy rates, and more of each of the vaccines. The article originates from a trusted source in the form of Yale University and was reviewed by a practicing doctor at Yale. Furthermore, no hint of bias towards one

company is demonstrated, as the article starts off with the viewpoint that all of the vaccines listed are effective and useful in stopping the spread of COVID-19. The source was limited in its utility, as in terms of new, relevant information, it only associated the different companies with the specific type of vaccine they produced, whether it be mRNA, protein subunit, or vectored.

Larson, H. (2020, March). *Why rumors about vaccines spread - and how to rebuild trust* [Video]. TED. https://www.ted.com/talks/heidi_larson_why_rumors_about_vaccines_spread_and_how_to_rebuild_trust

Through her talk, Larson discusses vaccine hesitancy caused by the spread of rumors relating to vaccines. Within this broad topic, she describes the various causes of vaccine hesitancy, including how intertwined vaccines have become with politics, and places emphasis on how the relationship between the scientific community, or more specifically the medical community, and the general public has grown to be strained over the past few years. This is all in an effort to change the way in which the medical community communicates with those who simply have questions about vaccines to encourage vaccination. Given in the context of the COVID-19 pandemic, her experience with working as the director of the Vaccine Confidence Project and with UNICEF, experiencing first-hand the rumors that caused the public to refuse vaccines, bolsters the reliability of her perspective in regards to the cause of vaccine hesitancy. With the talk, an additional appreciation for the importance of communication between scientists and the public due to its crucial role in preventing mistrust in science was obtained, and it introduced the possibility of researching organizations and groups relating to the topic of vaccinations and the medical community as a whole for their role in the debate about vaccines.

Libster, R. (2014, November). *The power of herd immunity* [Video]. TED. https://www.ted.com/talks/romina_libster_the_power_of_herd_immunity

In her lecture, Libster discusses various ideas relating to herd immunity, such as what exactly is herd immunity and the effect of Andrew Wakefield's journal relating vaccines to autism on herd immunity, which was an attempt to encourage the public to receive vaccinations against preventable diseases. Libster's TED Talk was found through searching the TED Talk website of various lectures relating to vaccinations and the public. While there was a clear persuasive slant in her talk towards encouraging vaccinations, all of her argument was supported by personal anecdotes and logical conclusions relating to the effects of herd immunity. This is substantiated when considering her expertise on herd immunity, as Libster is a proven expert in the domain of vaccinology and epidemiology. As part of her talk, Libster offered a basic definition of the threshold required for herd immunity, but it mainly consisted of information that was already gleaned from another source.

Mandal, A. (2019, June 5). *Vaccine Delivery.* News Medical. https://www.news-medical.net/health/Vaccine-Delivery.aspx

Found through a Google search about the innovations in how vaccines are administered, Mandal's article covers the various ways in which vaccines have traditionally been delivered and the new innovations in how vaccines might be delivered in the future. Along with this, she describes how vaccines are prepared before administration and other scenarios that require vaccine administration deviating from the norm. Mandal has extensive experience in the medical field and additionally has experience in simplifying the complexities of medical research, illustrating her expertise in the field of vaccinology and explaining why the article appears almost too simplified. Coming in with the intent of learning more about the newer delivery methods that were mentioned in prior research, the article fails to deliver much detail past simply listing the innovations being developed. Despite this, Mandal does list technologies, such as microneedles,

that were not mentioned in the sources used before her article, so she does present helpful launching points for further research.

Palfreman, J. (Writer & Director), & McMahon, K. (Director). (2010, April 27). The Vaccine War. (Season 2010, Episode 16). [Tv series episode]. In D. Fanning (Executive Producer), *Frontline*. WGBH Educational Foundation.

"The Vaccine War" was found through searching the catalog of episodes on *Frontline*'s website, which was known about through prior experience. The episode detailed each perspective and the various opinions held by pro-vaxxers and anti-vaxxers, starting first broadly with a format of a concern held by an anti-vaxxer, such as the heavy load of the vaccine schedule, and then the response by healthcare professionals to that concern. From there, it narrows in on the theory that vaccines cause autism and the effects of anti-vaxxers' claims on herd immunity. While journalistic bias has been at the forefront in recent times, the episode nor its producers appear to have a particular agenda that they are pushing in favor of either the pro-vaxxers or anti-vaxxers, as equal time is given to both sides to express their view authentically. In regards to the slight antiquity of the source, many of the points made in the episode are frequently referenced in more recent sources of information about vaccines, which, when combined with how the information given in "The Vaccine War" was told by an expert in the field or backed up by scientific studies, compounds the utility of this as a source of research today. Not only did the episode shed additional light on the opinions held by each camp when it comes to vaccines, the episode also allowed for the realization that the public has to depend on each other more so than they do on vaccines when it comes to herd immunity, showing that the interdependence between the public and vaccines is more so a pseudo-triangle than a linear relationship. It also emphasizes the importance of proper communication between health officials and the public, which is another topic of interest that vaccines are an example of.

Poon, J. (2021, March 29). *The Importance of Vaccinations and Maintaining Global Health*. Presentation, Virginia Beach.

Through her presentation, which was found through searching the database of MSA Senior Presentations, Poon aims to give a brief but informative general overview on the nature of vaccines and their importance in maintaining worldwide health. Poon goes from first defining what truly is a vaccine and narrows in on certain topics within the realm of vaccination, such as the various types commonly used to provide immunity and vaccines' relationship with the population. Although Poon's simplicity hampers her presentation's clarity at certain times, it did work for the most part in delivering her information and demonstrates her mastery of the complex topic of vaccines. Her qualifications in regards to vaccines are also boosted by the fact that her interview with a registered nurse, Jessica Daen, who has definitive experience in the field. Written in the current context of the pandemic, Poon's presentation provided a basic foundational understanding of vaccines from which further points of research can be gleaned.

Pöri, P. (2018). *Development of Vaccines* [PDF file]. Theseus. https://www.theseus.fi/handle/10024/143068

Found through Google Scholar, Pöri's thesis gives a more in-depth version of the overview given by Poon in her presentation and podcast, covering the types of vaccines, their history, vaccine development, and their future in addition to other topics. While there were no hints of persuasion or bias, the author sometimes hampers their paper with the occasional syntax or grammatical error in addition to some oversimplifications of various ideas, but most of Pöri's information is corroborated by Vetter's article, allowing it to still be seen as trustworthy. However, with this in mind, this source did not add much of value in regards to its intended purpose of broadening upon the understandings held of the vaccine types, as it offered information that was already found in another source. This thesis still was useful, as it allowed

for confirmation of the information already found in Vetter's article, and also gave information that could be used as background knowledge of another research topic, such as the future of vaccines.

Vetter, V., Denizer, G., Friedland, L. R., Krishnan, J., & Shapiro, M. (2017). Understanding modern-day vaccines: what you need to know. *Annals of Medicine, 50*(2), 110-120. https://www.tandfonline.com/doi/full/10.1080/07853890.2017.1407035

This article, found through searching Google Scholar with a variety of combinations relating to the types of vaccines, broadens upon the understanding gleaned from Poon's presentation about the contents of vaccines and how exactly each type is made in an attempt to clarify the existing misconceptions surrounding the domain of vaccinology. In doing this, Vetter and his coauthors first begin with a general overview of how vaccines work in conjunction with the human immune system and then discuss each of the vaccine types in detail, covering the specific antigen found within, the process in which they are made, and various relevant examples of each. In addition, several brief mentions of herd immunity and the future of vaccines are made within the source. Being one of the more erudite sources here, each of the authors appear to have extensive knowledge of each type of vaccines, as they all work in some business relating to healthcare. Although the article and authors are supported by several pharmaceutical companies such as GSK and Pfizer and do aim to increase the public's confidence in vaccines, none of the language within the article is overtly persuasive or one-sided; for example, they demonstrate this by their transparency in noting the limitations of each type and vaccines as a whole in some aspects. With this source, the sometimes-ambiguous overview of the vaccine types given by Poon was clarified to a great extent. It comes with the added bonus of stoking additional interest for future research topics like herd immunity and the future of vaccines.

Williams, N. & Poon, J. (Hosts). (2020). *Under the Scope* [Audio podcast]. Anchor.

https://anchor.fm/underthescope101

Found through the perusal of Poon's senior project portfolio, Williams' and Poon's podcast furthers upon the brief introduction given about vaccines in Poon's senior presentation in addition to covering topics in the domain of microbiology. For vaccines, Poon mainly offers an introduction into the molecular workings of the types of vaccines, and for microbiology, Williams explains antimicrobial agents as a major point of discussion. Although the two hosts do peddle various viewpoints and advice when it comes to antibiotic resistance or the upside of vaccines and herd immunity, their opinions are bolstered by what appears to be extensive research and interviews from professionals within their respective domains: Mary-Margaret Fisher, a lab operations manager at CHKD, and Registered Nurse Jessica Daen. Similar to Poon's presentation, the simplicity that the hosts use leaves certain ideas ambiguous but overall still delivers their information well enough. The podcast's utility in regards to further research is masked by Poon's senior presentation, as there were a lot of repeated generalizations within the podcast that were already gleaned from the presentation without the in-depth elaboration as was expected before listening to the podcast. However, the podcast did prove helpful in realizing the connection between microbiology and vaccinations.

Personal Finds, Plans, Musings

- It seems ironic looking back on it, but maybe a second look at the discussion within this recording will make more sense after the I-Search?
- Look for any interests in A&P and Microbio next year and list them here:
    -

Senior Project Ideas