# The impacts of SARS-CoV-2 on public health counter measurements in the 21$^{st}$ century

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**Abstract:** The spread of COVID-19 globally can be viewed as a historical pandemic within the 21$^{st}$ century. Like all historical major pandemics, the public health system evolves accordingly with new or improved counter measurements. The key aim of this review is to inform the audience on how far public health counter measurements has changed due to the pandemic. Observation and case studies will be utilized to better analyze the consequences of different approaches towards the pandemic. Identifying the flaws and reviewing the improvements that could be possibly imposed to our public health system would be essential when facing a future viral outbreak.

## 1. Introduction

On December 31$^{st}$, 2019, the 'Severe Acute Respiratory Syndrome Coronavirus 2' or commonly known as COVID-19 outbreak was reported to the World Health Organization. Over the course of roughly over a year, the original outbreak has now become a devastating pandemic responsible for millions of deaths and millions more infected worldwide. The virus possesses unique characteristics that allows elevated rate of transmission. It could cause severe respiratory problems and in extreme cases, death. As stated by Dr. J. Howard Beard, the author of '*The Contribution of Cholera to Public Health'* "Disease which do most for public welfare strike suddenly, kill quickly, destroy commerce, and cause panics" (Beard, 1936). It is certain COVID-19 is one of those disease due to its high virulence and infectiousness between hosts. Humanity's most effective defense against contagious diseases is public health, its counter measurements would also be one of our main focuses.

The pandemic has surely raised a red flag for all individuals and communities. It has proven how our current model of containment is ineffective towards this more contagious and deadlier virus as an outbreak soon escalated to an international pandemic. Therefore, it is logical for us to question what aspects of public health has been changed by the pandemic? This would be further classified into short-term counter measurements and long-term counter measurements. Identifying the flaws within the counter measurements would be critical for us as to seek for improvements. We need to determine ultimately how far public health system has been shaped by COVID-19 specifically to better combat against future outbreaks. It is crucial to first understand the fundamental biology of the SARS-CoV-2 and how it causes harm to its host. It is essential that we look at how these measurements function and what aspects were altered by the pandemic. I will discuss how SARS-CoV-2 shape public health counter measurements in terms of the problems it has exposed.

## 2. Origins and routes of transmission of SARS-CoV-2

One of SARS-CoV-2's potential carrier are wild bats. Although the virus might be virtually harmless to bats, it has proven to be lethal against humans. Through evolution, viruses have evolved to infect specific species within a class of creatures (Wacharapluesadee et al., 2021). However, it is important to understand how viruses can 'jump' across closely related species. As humans come in close contact with the habitats of bats, the virus can infect humans, hence COVID-19 is also classified as a zoonotic virus because it had jumped from one specie to another. SARS-CoV-2 might be living in harmony within bats, yet it can cause significant harm within humans. Bats have a very low inflammatory response towards the virus, causing no pathological damage. It is therefore counterintuitive to say that our immune system in this case is the one responsible for damaging our body.

The method of transmission of the SARS-CoV-2 virus also can't be undermined. Short-range transmission can be caused by droplets around 100 μm< in size, direct contact, or fomite. Long-range transmission can be achieved through aerosol <1 μm in size or fomite. It is transmitted mainly by respiratory droplets and aerosols (Anderson et al., 2020). This makes COVID-19 an extremely infectious virus compared to other viruses such HIV via body fluids, blood or H5N1 via direct contact, allowing it to spread sporadically shown in Figure 1.

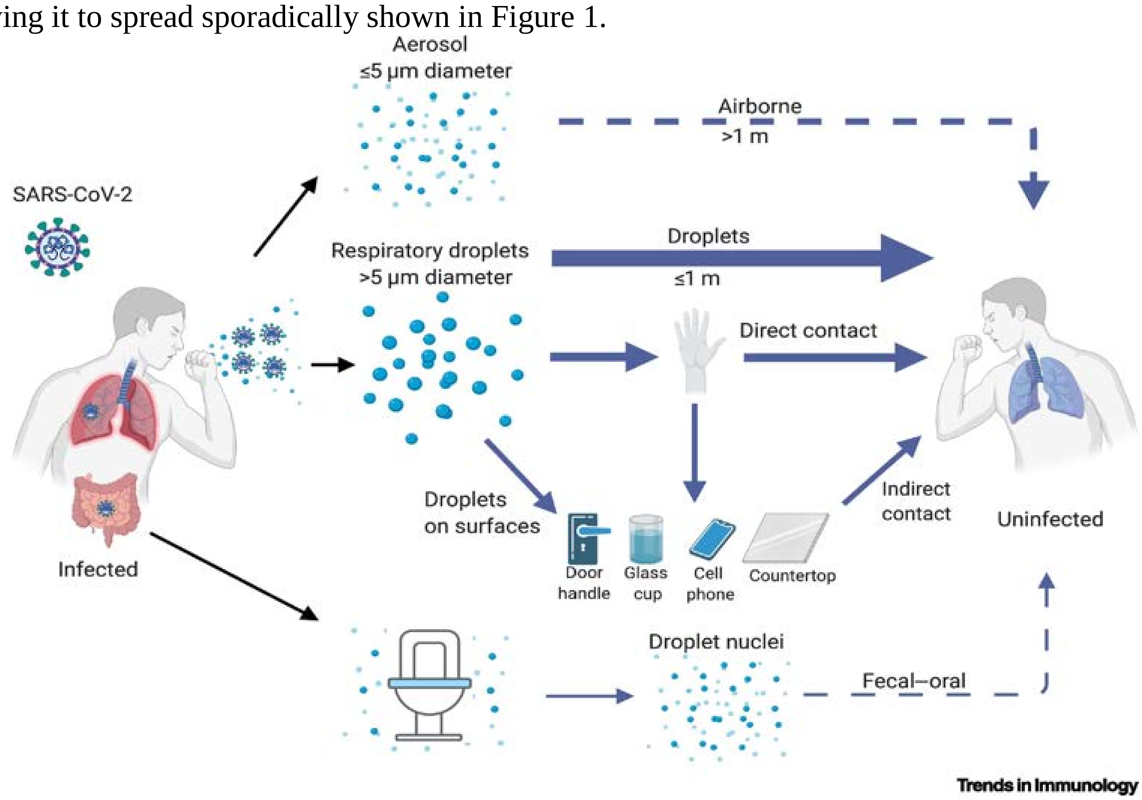


Figure 1. A display of how SARS-CoV-2 transmits via aerosol and droplets

## 2.1 The biology of how SARS-CoV-2 invades our body and causing harm

Like all viruses, the SARS-CoV-2 virus requires a host to replicate. After entering the host's respiratory system, the SARS-CoV-2 virus would target specifically alveolar type II cells by binding its spike protein S glycoprotein with angiotensin-converting enzyme 2, which is better known as 'ACE2' receptor. This grants the virus the ability to enter the cells freely through endocytosis indicated in Figure 2.

In humans, this foreign pathogen would also cause an immune response. As the virus divides and infects healthy cells rapidly, the immune response would be as vigorous respectively. However, as the macrophages attack the virus, it will release inflammatory molecules called chemokines. The molecule could activate more immune cells to target and kill infected cells. Dead cells and fluid accumulate within the alveoli which is the fundamental cause of lobar pneumonia or bronchopneumonia. Most common symptoms of COVID-19 therefore include fever, difficulty breathing, coughing and fatigue. The angiotensin system that mediates blood pressure and fluid and electrolyte balance would be heavily damaged due to the intense immune response or otherwise known as a 'cytokine storm' leading to its high virulence. In extreme cases, it would severely damage vital organs such as the kidney (Abbate et al., 2020), which would lead to blood pressure plummeting and the requirement of a dialysis machine.

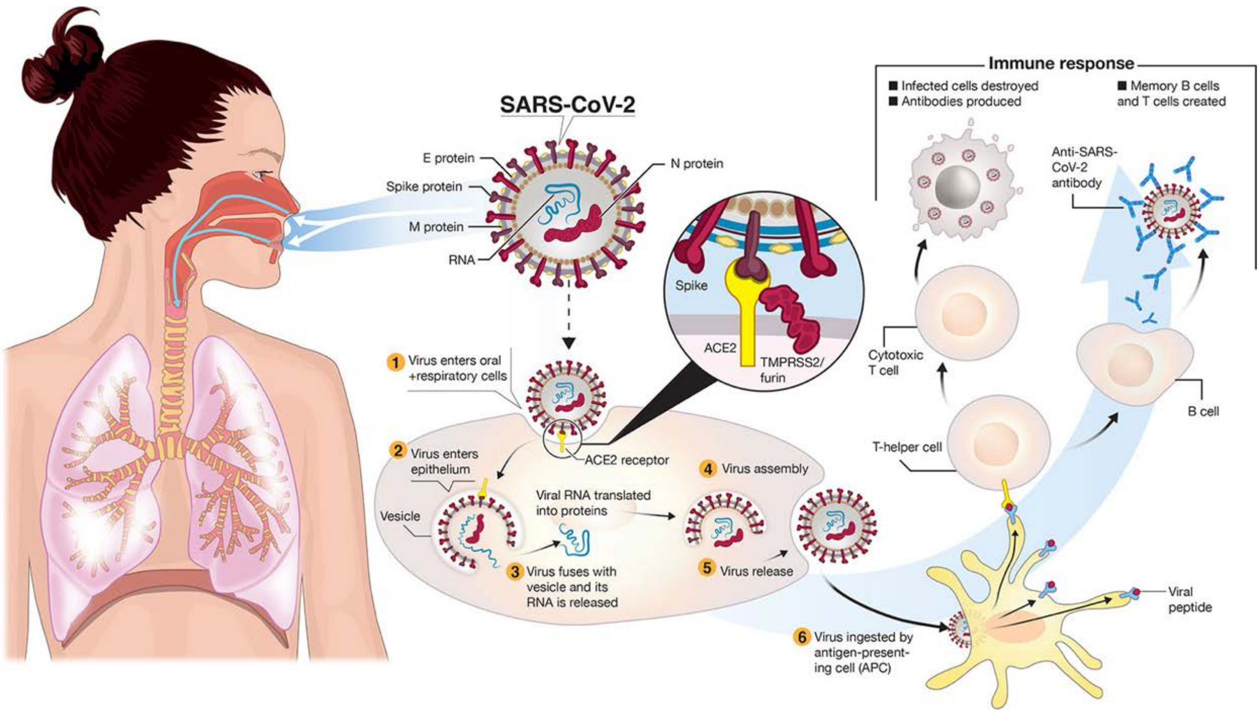


Figure 2. The process and mechanism of how SARS-CoV-2 infects host cells

## 2.2 The specialness of SARS-CoV-2 leading to its higher intrinsic infectiousness and virulence

In 2003, a SARS-CoV-1 outbreak occurred, yet it never escalated to a pandemic like its variant SARS-CoV-2. The fundamental difference between the two is the key to understand what makes COVID-19 more infectious. The characteristics of influenza viruses can be defined by two factors: their intrinsic infectiousness and virulence. When comparing, SARS-CoV-2 has a lower mortality rate than SARS-CoV-1, but significantly higher infectious rate, indicated by the $R_0$ value. The asymptomatic nature allows SARS-CoV-2 to rapidly infect individuals before symptoms begin to occur (Gao et al., 2020). It takes SRAS-CoV-1 and other viruses such as MERS 2-7 days before symptoms begin to occur and medical attention with isolation would be required. Onward transmission only began after onset of illness at $R_0 \approx 1$. By contrast, SRAS-CoV-2 takes up to 14 days before illness might occur, during this period the virus is free to infect exposed individuals at $R_0 > 2$-5 (Achaiah et al., 2020). By the time the patient has been quarantined, others might have already been exposed to the virus, some might not indicate any obvious symptoms. This makes it difficult to isolate infected individual from members of the public, which promotes the rate of infection. Due to the highly infectiousness, SARS-CoV-2 can spread swiftly among the population, which leaves elders vulnerable to the disease, meaning the virus also poses a high virulence. The two factors plotted on a graph would appear to look like in Figure 3.

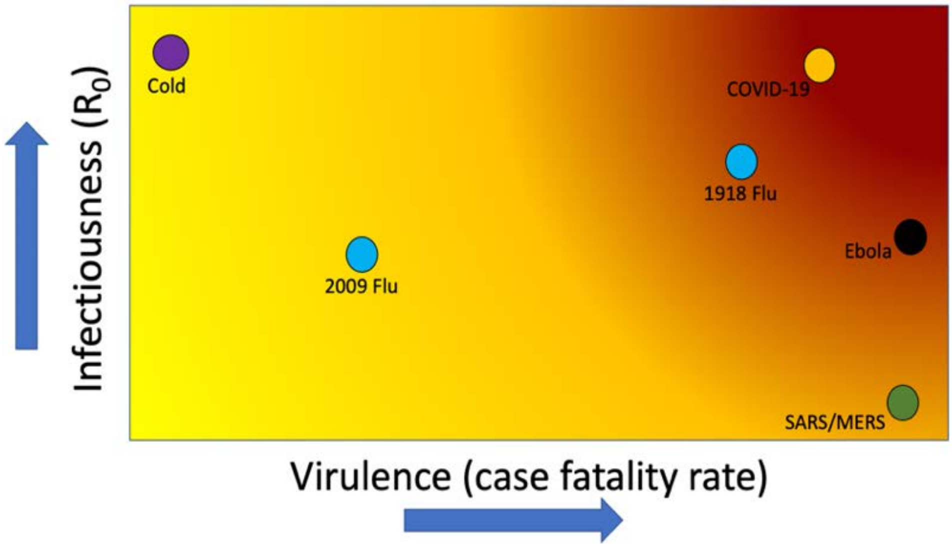


Figure 3. Graph indicating the virulence and the infectiousness of common viruses, including COVID-19

## 3. The underlying purpose of public health

As of the beginning, public health agencies were the first respondent to control the COVID-19 outbreak. The concept of public health was introduced by John Snow in the 19th century. Public health can be defined as the prevention of diseases and injuries within a population rather than treatments towards individuals. This involves non-communicable disease, natural disasters, and most importantly infectious diseases. It is also important to note that public health strategies are subject to change as we encounter new diseases and disastrous events. As all infectious diseases follow a general chain of transmission as shown in Figure 4, countermeasures against this cycle can be seen as public health. Public health therefore tackles the spread of the virus and aims to lower the $R_0$ value.

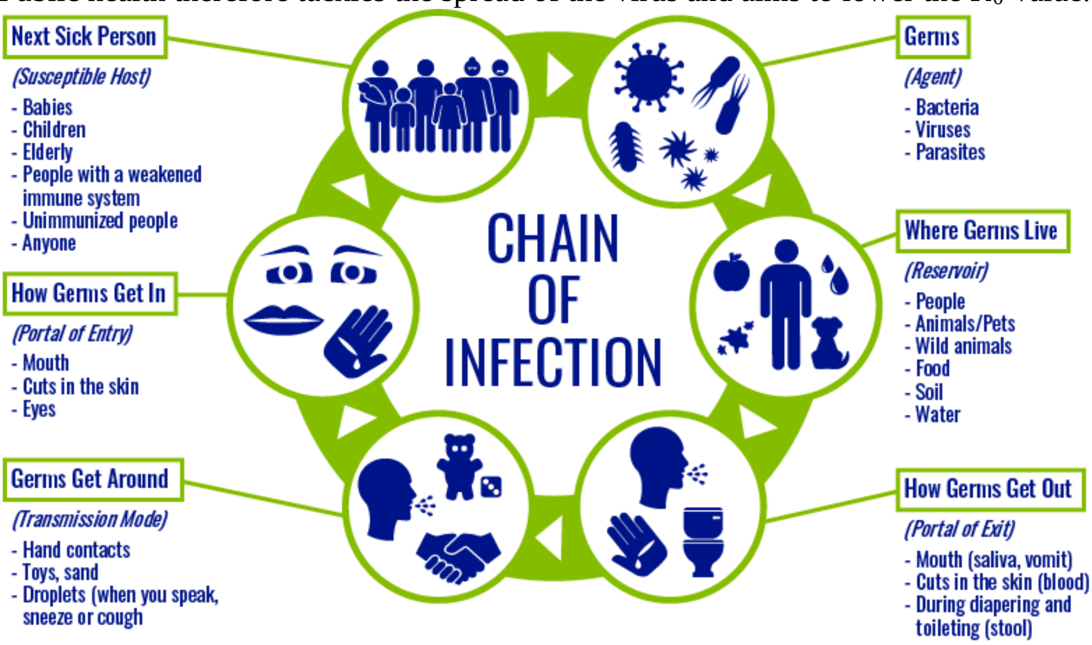


Figure 4. The chain of transmission

### 3.1 Short-term counter measurements: Encouraging and enforcing masks usage among the general population

The most common counter measurement introduced was the use of face masks in public areas. Like we discussed before, COVID-19 can be spread through droplets exiting our respiratory system.

A face masks therefore effectively covers all means of exit for the virus, which breaks the chain between means of exit and mode of transmission. SARS-CoV-2 enhanced this practice to a much greater extend as more became infected. This resulted in a huge shortage of masks in March 2020 (H. liang Wu et al., 2020). As of my opinion, these shortages would restrict the effectiveness of controlling the outbreak as medical staffs are unable to operate without protection. Individuals also became vulnerable without effective protection. In developing countries, the reliance on developed country became more obvious as they are unable to self-sustain under these extreme circumstances. Other supplies such as disinfectants, therapeutic medicine and uniforms were also low on supply. COVID-19 therefore illustrated the production of medical supplies and logistical issues currently needed to be reflect on and improved.

### 3.2 Quarantining individuals considered to be suspected carriers of the virus

Like mentioned before, patients infected with SARS-CoV-2 only shows symptoms after roughly 14 days, which grants the virus an abundant amount of time to spread from host to host. As international travel became more accessible, strict quarantine regulations has proven great significance in terms of containing the virus. The major difference between quarantine and isolation is quarantine target not only individuals showing symptoms, but also possible carriers (Li et al., 2020). A combination of strict testing is carried out to make sure if individuals are free of the virus. Hence, in my opinion COVID-19 caused regulations to become stricter with longer periods of isolation and more frequent testing. What COVID-19 did emphasize to public health agencies is the importance of isolating close contacts due to the high infectiousness of SARS-CoV-2. It made quarantining healthy close contacts tested negative, and people suspected of COVID exposure common because symptoms occur late before individuals are aware that they have been infected. This unfortunately cause distrusts among the public, which would result in infected patients not reporting to authorities. Hence, the pandemic made public health guidelines towards identifying subjects needing to be quarantined broader and more rigorous to make sure under no circumstances the public might expose to an infected, 'healthy' individual.

### 3.3 Government authorities imposing a city wide/ national lockdown

On 23 January 2020, the government of China imposed a lockdown in Wuhan including other cities in Hubei province as an effort to contain the virus. This extreme counter measurement has never been seen before prior to the outbreak. Even during the era of the Spanish flu, lockdown was not imposed as local pubs and sports events still took place as usual. A lockdown simply regulates the movement of people, which prevents infections to spread. It is being enforced by the government and must be imposed for a considerable period before results could appear. It drastically decreases unnecessary contacts between people. Although a lockdown can oppose serious damage to the economy, its ability to effectively stop cases from spreading further cannot be undermined. We can analyze data to visualize the impact a lockdown could potentially bring. One of the first country to impose a lockdown was China, its active cases are shown in Figure 5. It is obvious how after the lockdown of Wuhan was introduced, in roughly three months, cases were under control.

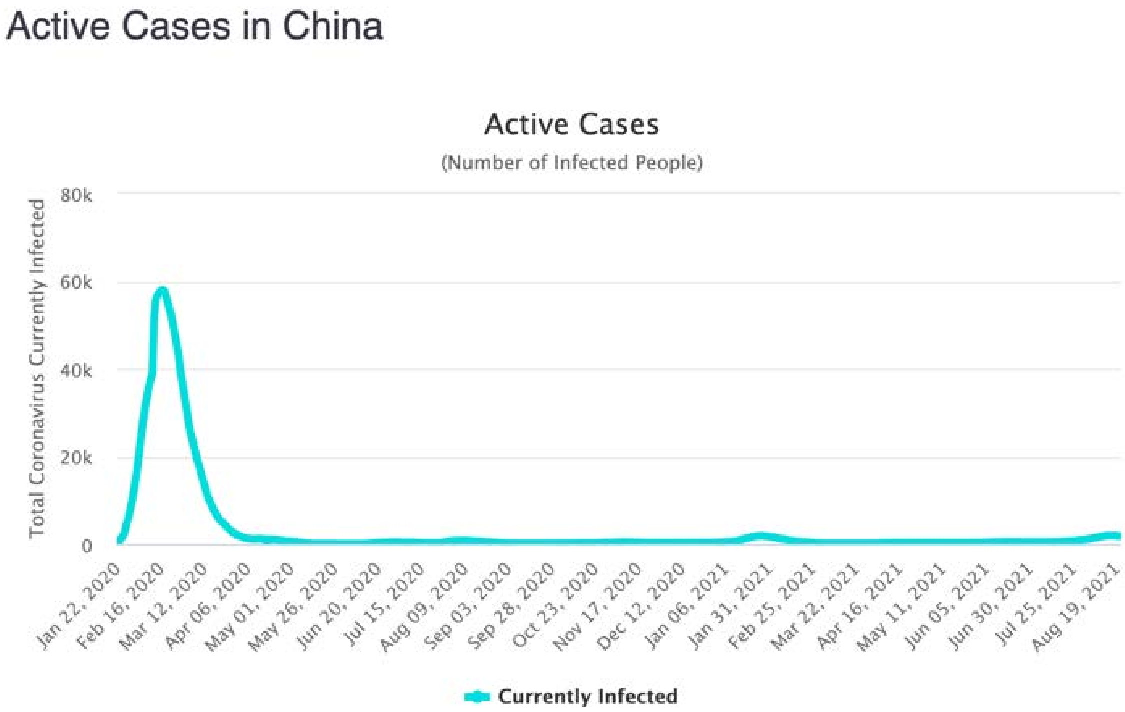


Figure 5. Graph indicating the active cases of China

A lockdown must be imposed with enough enforcement and determination to obtain obvious results. It cannot be considered as a last-ditch effort to stop the virus from spreading, it should be one of the first strategy imposed (McTague, 2020). In the UK, a lockdown was imposed too late which caused cases to skyrocket shown in Figure 6. A national lockdown was introduced on the 5th of November yet lasted for only 4 weeks until the 2nd of December. The graph suggests how numbers gradually stopped rising after a national lockdown was introduced in November, there is even a small decline in the number of cases. However, just weeks after the national lockdown ended, cases began to rise fast. From my perspective, it is possible the new variant firstly being introduced in the UK could have made containment more difficult, yet it is clear how a lockdown could seriously slow or even stop cases from inclining.

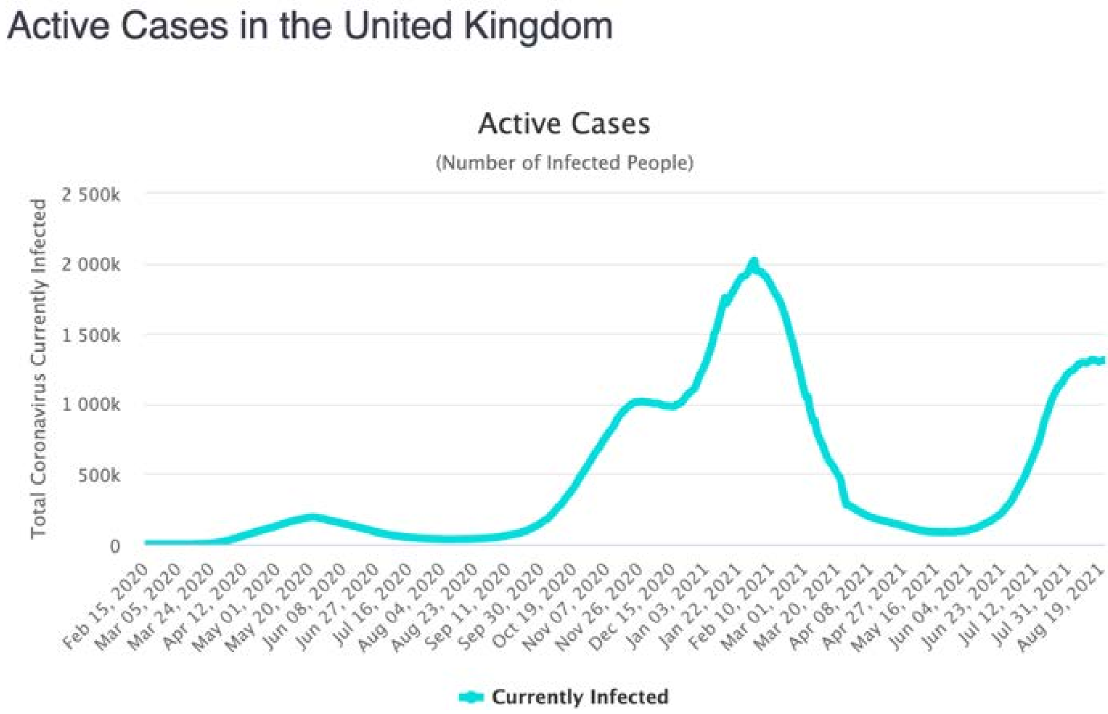


Figure 6 Graph indicting the active cases of the UK

I therefore view the pandemic has molded a completely new, extreme strategy that could potentially be used by public health agencies and governments in the future to effectively control the spread of an infectious disease like COVID-19. It has proven great significance by controlling the spread of the virus in a city with a high population density, though comes with a costly price.

### 3.4 Diagnostics towards the SARS-CoV-2 virus

Diagnostics plays a vital rule when combating infectious disease. It allows the identification of infected individuals, in which they can be isolated and treated.

There are currently two dominant methods of diagnosing SARS-CoV-2: Nucleic acid amplification tests and antigen tests

#### 3.4.1 Nucleic acid amplification Test

Nucleic acid amplification test, more commonly known as tests, involves amplifying the presence of the viral RNA fragment to determine whether if the person is infected or not. Each cycle of replication consists of three steps: Denaturization, annealing and extension show in Figure 7.

After isolating the RNA, the sample would be mixed with reverse transcriptase, DNA polymerase, nucleotides, forward and reverse primer. The amplification test mainly targets sequences in the N, E and RdRP gene of the virus. The first step of reverse transcription is the reverse primer hybridizing to the complimentary section of the RNA genome. The reverse transcriptase enzyme will then synthesize the addition of nucleotides onto the RNA. The temperature of the chamber will then rise to 95°C, which denatures the DNA. Annealing requires the temperature to drop down to 58°C, allowing the forward primer to bind to its complimentary section. In the extension phase, the DNA polymerase would then attach the matching nucleotides by adding free nucleotides. TaqMan Probe containing fluorophore can be added, which emits fluorescent light that can be detected by the machine to determine the presence of the viral RNA (La Marca et al., 2020). Obviously, this test can detect even with the slightest presence of COVID-19, yet it requires a long duration of time, about 6h<, expensive equipment, high level of expertise, making it fundamentally costly. As the virus is extremely infectious, the results might not be valid as individuals might still catch the virus. I therefore believe COVID-19 has proved how public health cannot mainly rely on this accurate but long and expensive tests due to SARS-CoV-2’s high rates of infection. However specialized nucleic acid tests that follows a principle of isothermal amplification are promising as results accuracy are like PCR tests and much quicker than PCR test. The antigen test on the other hand is much quicker, but also come with its flaw.

#### 3.4.2 Antigen Test

The antigen test is a much simpler testing method. The sample containing the virus would be disrupted by reagents inside a pipet, this exposes the antigen of the virus. The solution will be dripped onto a lateral flow template. Dyed monoclonal antibodies will bind to the antigen forming an antigen-antibody complex. After diffusing along the strip, it would reach the testing line containing immobile antibody that would bind to the complex. A colored strip will occur if SARS-Cov-2 antigens are present.

The antigen test obviously can be carried out faster, cheaper, and easier. This allows more to be tested and can be done regularly by individuals. Subjects that are infected can be isolated effectively as the results appear just under 15 minutes. However, the problem with antigen testing is that it could only detect individuals infected with relatively high levels of the virus. In addition, there is a chance of a faulty test. The test can be done on a regular basis to indicate the ones infected, rather than taking a PCR test when needed or symptoms began to show.

#### 3.4.3 Future of Diagnostics

Both techniques contain its advantage along with its disadvantage. The pandemic showed a new diagnostic method should be developed to better combat an extremely infectious disease like COVID. A successful diagnostic method should be cheap, accessible, accurate, easy to operate and gives out results fast. Diagnostics done on a more immense scale can allow public health agencies to effectively understand the distribution of healthy and infected individuals, suitable strategies may then be developed accordingly.

One possible idea is to use mass spectroscopy to detect molecules related to specifically individuals infected with COVID (SoRelle et al., 2020). The mass spectrometer operates on the idea that different molecules and elements consist of different mass. As they are being ionized through electrospray, a negative plate is to accelerate them. The ionized molecules will travel in different velocity, the relative mass of the molecule can then be calculated, which reflects the composition of the molecule. From my perspective, although this method is quite new, yet it brings much potential of an effective diagnostic tool. However, creating a data library for the antigens of COVID-19 can be difficult in the first place. COVID-19 therefore promoted the improvements of public health counter measurements.

## 4. Long term counter measurements: Vaccinating individuals to become immune of the virus for a duration of time

### 4.1 The practice of vaccination isn't uncommon throughout history

Conventional vaccines consist of injecting a weakened or inactive version of the virus. Protein-based vaccine mainly involves introducing a small amount of the appropriate antigen to the body either by mouth or injection. If the same pathogen enters, it will then stimulate a more immediate, greater response. Although different types of vaccine have different effectiveness.

mRNA vaccines directly inject the lipid nanoparticles containing mRNA as RNA is hydrophobic required to produce the SARAS-CoV-2 antigen into the body (Reichmuth et al., 2016). The body cells would then produce viral antigen that can be identified by our immune cells such as helper T cells and stimulate an immune response. Some mRNA vaccines might include an additional mRNA coding for the enzyme RdRp which can produce multiple copies of the antigen encoding mRNA, hence amplifying the production of antigens. mRNA is undoability the most effective vaccine out of all other types of vaccine. However, there are still debates towards vaccines causing epigenetic changes and causing blood clouts.

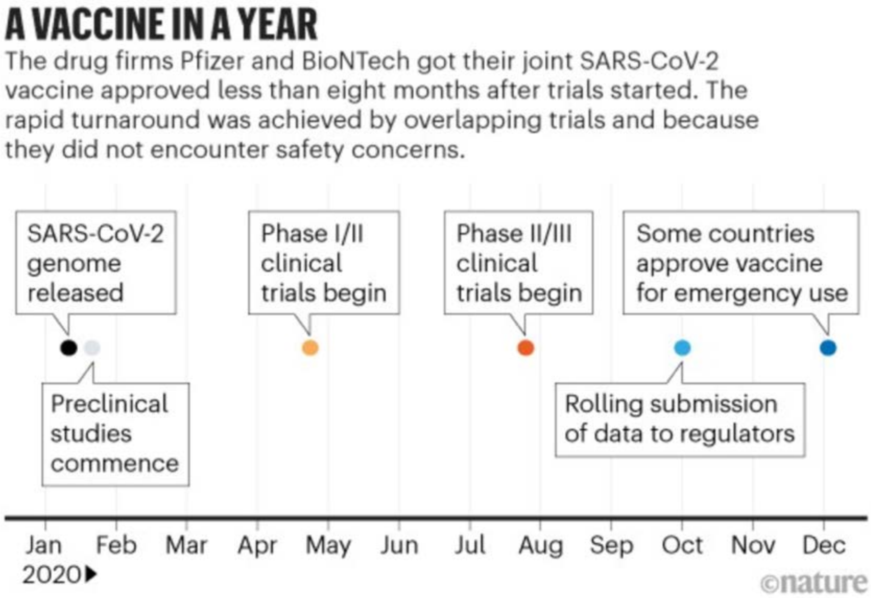


Figure 7. Timeline indicating the production of COVID-19 vaccine

Usually, a new vaccine takes up years of time before it could be introduced. This is mainly due to the testing phase, in which companies need to analyse financial risks before blindly testing. After testing the vaccine on animals or cells, it will then be tested on humans including three phases. The reason the SARS-CoV-2 vaccine was produced and administered within a year is mainly due to massive funding. Another significant factor was the publication of the genomic sequence of SARS-CoV-2 within weeks of the outbreak by Chinese scientists. Companies can then conduct phase I, II and III trials as well as manufacturing in parallel rather than traditionally in sequence shown in Figure 8. The vaccine targeting the Ebola virus did not develop as fast as the SARS-CoV-2 vaccine due to the lack of funding. The pandemic has proven to public health agencies that unless institutions are funded generously, vaccines cannot be made swiftly (Ball, 2021). Not to mention that prior research towards SARS and MERS assisted the discovery of the new vaccine. I therefore believe the pandemic has allowed us to understand our potential in creating a vaccine. It made us aware that a collective effort of prior research, new technologies and funding could offer much potential.

### 4.2 Achieving herd immunity among a population via vaccination programs

The concept of herd immunity is based on the idea that foreign pathogens can spread when people are in close contact. If most of the population has been vaccinated, it would be much difficult for the virus to spread. People who gained immunity by exposing to the virus would also protect the ones vulnerable shown in Figure 9. The practice does not biologically decrease the infectiousness of the virus, but rather lower its external infectiousness. Herd immunity is potent as it is almost impossible to vaccinate the whole population. This can be cause by individuals having a compromised, weak immune system or simply holds a negative view towards vaccination. For herd immunity to take place, the most critical factor is synchronizing all the vaccination program. As vaccines are not permanent, by having most of a population immune for a certain period would significantly interrupt the spread of the virus.

SARS-CoV-2 pandemic really showed how a lack of consistent vaccination can have devastating results. Looking at the US vaccination program, the slow start has caused inconsistency in their vaccination program. This is mainly due to their complex health system, services that could report to local officials or operates independently. Coordination between these services can become extremely difficult. Logistical problems and administration problems began to arise. ‘As of 20 January, more than 35 million vaccines had been distributed across the US, but less than half of these had been put into people's arms.’ (Horton, 2021) Lack of funding from the government made setting up vaccination camp and hiring staffs hard. The pandemic has showed public health agencies the importance of a clear system for transporting and administrating vaccines. I believe it showed how perhaps public health agencies should have more authority in times of crisis to “get things done” before the situation escalates. Vaccination might become essential and enforced to a greater extend.

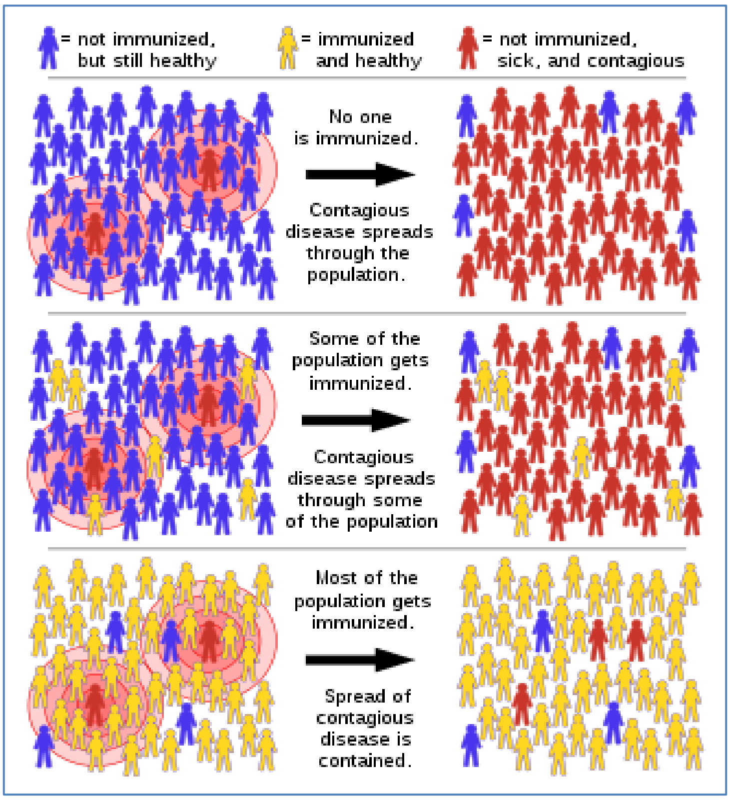


Figure 8. Visualizing herd immunity within a population

### 4.3 Therapeutic drugs against viral infection such as SARS-CoV-2

By curing the sick, it is also a method to protect the healthy. Unfortunately, The SARS-CoV-2 pandemic indicated that public health was not prepared with the therapeutic front against the pandemic. There was never an effective way to eliminate viruses directly. By now, the most effective therapeutic drug are monoclonal antibodies designated to block the spike protein of SARS-CoV-2 from entering a body cell, also known as neutralizing antibodies. Other therapeutic drugs aim to fight the symptoms of COVID-19, yet highly ineffective against killing the virus. The use of monoclonal antibodies is highly specific to one antigen only, meaning it can only be produced when a new pathogen is discovered. However, it is undeniable that the lack the type of antiviral drugs that are "off the shelf" makes it difficult to treat patients effectively, therefore accelerating the spread of the virus. (R. Wu et al., 2020). In my opinion, the pandemic made us aware it is perhaps necessary to focus on developing antiviral drugs that can be highly effective against a broad variety of viruses. If this can be achieved, our defense against viral infections would be drastically strengthened as people can be treated effectively, hence controlling the spread of the virus.

### 4.4 Collective genomic surveillance of SARS-CoV-2

Genetic sequencing is the practice of decoding the genome of SARS-CoV-2. This is particularly helpful for scientists to understand how the virus is mutating and how it is transmitting. This information can then be used to create a vaccine accordingly. Before the pandemic, decoding genomes were common as it can be used for studying antibiotic-resistant bacteria, monitoring influenza strains or investigating outbreaks. However, this has now caged significantly due to COVID-19 (Cyranoski, 2021). The practice of genomic surveillance has allowed public health agencies to precisely track each strain and variants of SARS-CoV-2. This gave public health agencies time to impose counter measurements accordingly. The delta variant was identified and acted against within a few weeks of emergence thanks to genomic surveillance and counter measurements could be imposed accordingly.

## 4.5 Identifying and preparing for 'disease X'

Disease X is the term to describe an unknown pathogen that could bring serious international pandemics in the future. Foundations such as CEPI are responsible for identifying disease X to assist us in combating the pathogen in the future. It is stated how research in entire classes of virus should be conducted instead of narrowing into individual strains to better identify unforeseen strains. Combined with genomic surveillance, the threat of mutants would decrease significantly. It would allow us to track the virus and plan our counter measurements effectively (Mooney, 2021). Ambitiously speaking, I believe it is possible vaccines can be tailored to the different variants. As vaccines are administered swiftly, possibility of the outbreak escalating to a pandemic could be eradicated. It is even possible pan-viral vaccines could be developed to grant individuals immunity to families of viruses or mutants by identifying the genomic composition of viruses.

The chancellor of Germany Dr Angela Merkel said, "The current Covid-19 pandemic has taught us that we can only fight pandemics and epidemics together", which is the undeniable truth about this pandemic, collaboration is vital. This is because emergence of the virus cannot be predicted precisely. As disease X may cause a global pandemic, international collaboration is vital as disease X would "strike suddenly, kill quickly, destroy commerce, and cause panics". Sharing data and findings would allow the accelerated production of vaccines. Funding and direct support would help researchers and frontline medical staffs to better combat the virus. I therefore believe the most vital change COVID-19 has brought to public health counter measurements is the idea of deep collaborating on a global scale.

In conclusion, each major pandemic such as COVID-19 would likely shape our counter measurements accordingly, it will improve public health in general. Pre-existing measurements will be changed or improved on as new measurements will be invented, all to better contain the spread of the virus and break the chain of infection. New diagnostic and scientific inventions may be invented due to the virus. Our understanding towards epidemiology, pathology and science in general would advance. In the future there will always be disease X with high virulence and infectiousness lurking among our environments. However, the revolutionizing concept of researching and predicting disease X will ensure that we are prepared. The only issue then, would be if we were to unite together as one.

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