Proactive Not Reactive: Pandemic-Prepared Commercial Architecture

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ABSTRACT: Throughout the last millennium, humans have experienced four known respiratory pandemics: The Black Death in 1347, Tuberculosis (from the late 1800s, to mid-1900s), the Spanish Flu of 1918, and COVID-19 (current), that have shifted the way people thought about and used space. The Black Death, for example, introduced the concept of quarantining (Huremović, 2019). The Spanish Flu was the first major pandemic to introduce the notion that one could not simply 'escape' the sickness. Tuberculosis took quarantining a step further with revolving quarantine huts in which the patient was exposed to fresh air and would be turned to face the sunlight (Campbell, 2005). Lastly, COVID-19 called for the return to indoor quarantine rooms, with access to the outdoors restricted to limited numbers along with the highly suggested distance of six feet between people.
After the recent Ebola outbreak in 2014, the World Health Organization (WHO) created resources to track the research and development of existing diseases to better inform how to mitigate the next one, or 'Disease X' (WHO, 2022). This term gained traction as a placeholder to describe any pandemic caused by a pathogen (such as bacteria or a virus) currently unknown to cause human disease. Some medical experts believe that COVID-19 may not have been Disease X but instead is a milder version of what Disease X may be (Tahir et al., 2021). As medical professionals have recognized through the development and study of Disease X, it appears another pandemic is inevitable. This paper explores ways to use architecture to help better prepare for it.
This research aims to include architecture within this preparation process for Disease X to reduce the spread and effects of respiratory disease in pandemic conditions. In addition, this research will provoke an architecture that can reduce the spread of Disease X by analyzing existing architectural responses to respiratory outbreaks, interpreting architectural trends from the four major pandemics, developing a taxonomy of strategies, and proposing new ones for future outbreaks.

KEYWORDS: respiratory health, pandemic architecture, ventilation, daylighting, adaptive architecture

1. INTRODUCTION

Architecture and respiratory pandemics in the recent past have had a type of causational relationship in which a shift in public health forces the hand of architecture to change as well. Instead of acting proactively to address public health, architecture reacts in times of crisis which is evident in an examination of select respiratory pandemics' effects on architecture throughout modern history. This may be because after the success of antibiotics by the 1940s, "medicine was emancipated from architecture" (Fezi 2020). Healthcare had changed from preventing disease, to treating disease. Preventative strategies using passive building systems such as thermal massing to mitigate diurnal temperature swings, cross ventilation to provide fresh air, and positioning of building mass and windows to allow for proper daylighting, seemed to matter less and less as mechanical systems gained popularity. As air conditioning became widely used in the mid-1950s, amid a growing technological enthusiasm in the United States, concern for passive design strategies, such as orientation, shading, site planning, and ventilation, rapidly diminished (Böer 2019).

Before the reliance on mechanical systems, and the introduction of antibiotics, architecture was once considered 'part of a health system'. The Spanish Flu of 1918 for each involved hygienics in architecture, helping to pave the way for Modernist Architecture and urbanism (Fezi, 2020). It was also seen as the first truly global pandemic along with the first one occurring alongside the increasingly popular modern medicine (Huremović, 2019). A study on American cities during the Spanish Flu concluded that cities that involved non-pharmaceutical interventions, (NPIs) using methods such as social distancing early on during the Flu, fared better after the pandemic as compared to cities that were not as aggressive or proactive in fighting the disease. In fact, NPIs lowered mortality of pandemics and mitigated economic consequences (Fezi, 2020). But as modern medicine started to gain popularity, hygienics and architecture started to diverge. Architecture can work together with medicine and modern technologies by acting proactively, perhaps by building health-focused infrastructure into everyday lives. There may be no solution to entirely reduce humanity's ability to get sick, but architecture can play a role in mitigating the effects in dense, urban settings before they occur. Architecture can no longer remain a background character when it was "itself one of the technological alternatives whose role reciprocally destabilizes and shapes the others" (Adams et al. 2008). By examining respiratory pandemics and their impacts on architecture, one can inform how to propose a new pandemic-prepared architecture that balances new building strategies with beneficial modern technologies to be proactive instead of reactive with consideration for respiratory health in addition to energy, comfort, and cost.

Commercial architecture is one of the largest opportunities for these pandemic-prepared strategies as people typically spend up to one third of their lives at work (Pryce-Jones 2010), typically around other people. If proactive strategies are implemented within commercial office buildings to combat the spread of respiratory disease, the health benefits for the general workforce (and potentially the rest of society) could be significantly impactful. This research will look at the four major respiratory pandemics throughout history, analyze the effects these pandemics had on the local population/architecture, and make proposals for a pandemic-prepared architecture. As trends appear in the data, this research will inform possible solutions for Disease X such as adaptive architecture, daylighting strategies, and natural ventilation strategies.

2. BACKGROUND

The term 'Disease X' stands as a placeholder for the next pandemic humanity will encounter. It is "not, as of yet, an actual disease caused by a known agent, but a speculated source of the next pandemic that could have devastating effects on humanity" (Huremović, 2019). As mentioned previously, COVID-19 may not be Disease X but may be a milder version of what Disease X could be. In other words, COVID-19 is not the last pandemic. In fact, "virtually every expert on influenza believes another pandemic is nearly inevitable… that it could kill tens of millions… and that it could cause economic and social disruption on a massive scale" (Fezi, 2020). However, architecture can help play a role in preventative measures; to help mitigate the effects of the next pandemic before it occurs. For the purposes of these strategies, the next pandemic is assumed to be respiratory in nature and will follow similar transmission patterns such as the Black Death of 1347, the Tuberculosis outbreak of the late 1800s, to mid-1900s, the Spanish Flu of 1918, and COVID-19. Historical research and case study analysis of successful strategies (and unsuccessful ones) will provide the basis for the theoretical future. Architectural strategies of focus include adaptive architecture such as balcony and outdoor terrace space, daylighting through the inclusion of clerestories and light wells, and ventilation strategies such as double-skins, stack ventilation, and operable windows.

2.1 Quarantine and human density

The word *quarantine* derives from when the period of isolation or waiting away from others so as not to potentially infect people with disease, was later extended to 40 days or (quaranta giorni). During the Black Death in the fourteenth century, medical treatments were limited, so most measures to control the disease were movement-controlled measures such as isolation (see Fig. 1), quarantine, and confinement (Fezi 2020).

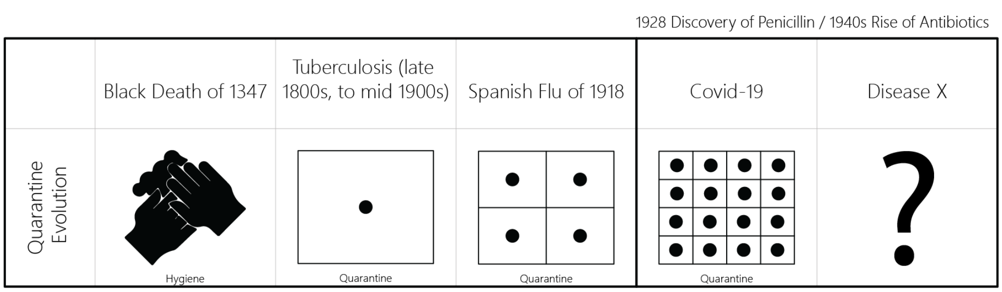

Figure 1: Diagram of the evolution of quarantine. Source: (Garceau, 2022).

During COVID-19, architecture (like in the Black Death with the quick solution of quarantine ships [mobile spaces for visitors to occupy before entering cities]) had to adapt rapidly from the open-concept movement of the 1970s to having to create separate closed-off rooms for people to occupy (Frith 2012, and Fezi 2020). The temporary adaptive architecture solution during COVID-19's time was utilizing moveable partitions in 'flex spaces'. These moveable partitions often have structural or acoustical issues that render it ineffective for use. The sterilization, UV lights, or plexiglass dividers also used to tackle COVID-19, became outdated very quickly as our understanding of disease transmission moved from droplets to an airborne disease (Carr et al. 2022). Furthermore, this still involved the concept of isolation, albeit on a much larger scale (see Fig. 1). For now, one can only predict the effects Disease X may have, but architecture's involvement (beyond the use of quarantined space) may help to mitigate the effects.

In the near year 2100, the world is expected to grow from around 8 billion to 11.2 billion (United Nations, 2019). To reduce the spread of disease indoors, architecture needs to approach design “through a health lens [which] can provide meaningful impacts for individual, population, and global health” (Dannenberg and Burpee, 2018). Architecture can help lessen drastic events from a future pandemic and has existing infrastructure to do so thanks to the previous pandemics. For example, with Tuberculosis, “after 1882, public health concerns that had initially focused on the provision of clean water and efficient sewers shifted to examining the poor physical state of working-class urban housing with a high incidence of Tuberculosis and respiratory diseases” (Campbell 2005). The idea of overcrowding (first brought to attention during Tuberculosis in the late 1800s, to mid-1900s) was revived during COVID-19, with the death rates spiking in the city. The challenge becomes acknowledging density issues and incorporating architectural strategies to help reduce the spread of disease. Regarding office buildings specifically, open spaces seemed to be the main contagious spaces in which COVID-19 spread the most, not because of necessarily the amount of interaction between workers, but the duration or length of contact workers had with each other (Fezi, 2020). This does not account for large social gatherings at the office, but instead concerns the ‘typical’ day of the office worker, as context for the scope of this research.

2.2 Adaptive architecture

Adaptive architecture is an all-encompassing term that groups architecture that can adapt to its environment, and the needs of its inhabitants (Schnädelbach, 2010). In the context of office buildings, this may include an architectural response that puts a focus on purposefully versatility, analyzed within specific case studies to provide a suggested foundation for pandemic-prepared architecture. During Tuberculosis, access to outdoor space became vital as fresh air was believed to be part of the Tuberculosis cure and it gave rise to the use of individual porches, or covered spaces outside so each patient could have personal access to the outdoors (Fig. 2). In this way, architecture “served explicitly as an active physical agent in tuberculosis treatment” (Adams et al. 2008) through outdoor balconies, expansive verandas, sunning galleries, and occupied rooftops (Campbell 2005).

Figure 2: Diagrams of outdoor terrace and outdoor balcony. Source: (Garceau, 2022).

As the introduction to antibiotics came on the rise, the balcony space shrunk (Fig. 3) as it was no longer required for patients to spend a majority of their time outside for the rest cure, showing the influence of disease on architecture during Tuberculosis and the Spanish Flu.

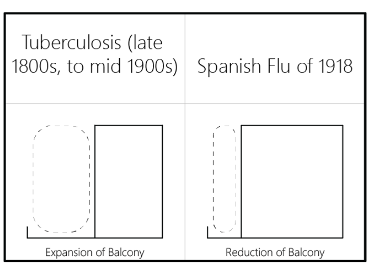

Figure 3: Diagrams of balcony declining. Source: (Garceau, 2022).

Other solutions that came out during Tuberculosis may not be practical due to climate reasons. Flat roofs, outdoor balconies, and roof or garden terraces are not well suited for all climates, particularly during extreme weather (Campbell 2005). However, access to outdoor space throughout the history of pandemics has proved imperative, with COVID-19 also leading to a reactivation of outside space, such as restaurants that used patios more due to limited space inside, the inclusion of more indoor/outdoor classrooms, and more ‘flex spaces’ such as walled off social distancing areas for people to gather. But these actions can be more purposeful within architecture and can relate closer to how one can involve access to the outside within an office setting. For example, CallisonRTKL designed an office building that incorporates access to the outdoors through adaptive architecture in the form of balconies (Fig. 2), terraces (Fig. 2), and rooftop design (Berg 2021). This case study is of 3901 Fairfax Drive, to be built in Arlington, Virginia. At the street level, an outdoor park space is available for corporate or public use, with the rooftop of the building containing a patio space, for informal working areas or open-air presentations. There is also an enclosed central conference room on the roof as well. Terraces are included on the second floor, connecting the office workers to street activity. In this example, the access to greenspace along with outdoor meeting areas, working terraces, and more are examples of adaptive architecture because these spaces are equipped to mitigate disease spread by providing spaces for humans to occupy under multiple conditions, whether the conditions simply be from the weather, or born out of necessity to prevent disease by spreading out and/or receiving fresh air.

The introduction to outdoor working space helps to transition into the need for proper daylighting and ventilation strategies. Furthering an exploration into what a *flex* or *in-between* space (Fig. 4) might consist of, 125 West End Avenue is a 3.4 acre automotive facility that is to be re-clad and renovated to be a research lab and commercial facility (Young 2022). The project is to be gutted in the interior and changed to have a spiraling ramp in the middle of the facility, with commercial space surrounding the ramp. Glass will clad the outside, allowing for natural light to fill the space, and the project also features a rooftop outdoor terrace. The winding circulation ramp connects the large main floors with smaller, more private areas for collaborative work. To elaborate further, the circulation ramp connects to the main floors, but in between main floors, there are also smaller transition spaces for people to work in.

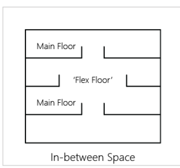

Figure 4: Diagram of in-between Space. Source: (Garceau, 2022).

In this case, the adaptive architecture consists of the transition spaces between floors, along with the outdoor terrace. The inclusion of these smaller spaces of floors in-between floors act as spaces that serve as zones in which people can still collaboratively work together, just more safely, due to the architecture's versatility. Regarding pandemic-prepared architecture, the idea is to purposefully design transition spaces that allow for flexibility in use, while not isolating people from each other. The 'in-between' space is connected to the main atrium and does not act as separate or as an isolated space but acts as a transitional adaptive architecture.

2.3 Daylighting

Sunlight was thought to be a cure for Tuberculosis, as it was good for treating vitamin-deficiency diseases at the time (Campbell 2005, Carr et al. 2022). The requirement for fresh air and exposure to sunlight during the Spanish Flu and Tuberculosis helped to evolve sunning galleries and occupiable rooftop space. During the Tuberculosis era, architects also were able to use new structural steel which was able to remove structural responsibilities from the building envelope and maximize sunlight exposure. The use of structural steel in construction (with the absence of interior structural support) also meant that fresh air had an easier time circulating within the building itself, because the building could be more open (Adams et al. 2008). The term *light and air* became popular in architectural discourse during the Tuberculosis pandemic, with architects creating open, large expansive rooms with extensive glazing "to free the interior space from the dark, claustrophobic, germ harboring" spaces of before (Campbell 2005). These impacts of 'light and air' made their way into the architectural Modernist movement of the early to mid-1900s. This movement is characterized using expansive glass along with steel. The flat roof (Fig. 5) specifically became popular during Tuberculosis as an architectural style for more individual units, such as homes, because a popular cure location of Davos Dorf and Davos Platz in 1865, had an issue with those retreating to this fresh mountain air town getting impaled by icicles from the roofs of the village homes or small shops. Thus, the early flat roof as we know it today was designed so icicles would not form and potentially fall on visitors (Campbell 2005).

One solution these Modernist architects had to allow light and air into dense housing was to implement a stepped-terrace system utilizing the recent popularization of flat roofs. In this way, the flat roof did not necessarily help fight Tuberculosis but instead came because of Tuberculosis. Contrastingly, Tuberculosis sanatoriums (Fig. 5), or large buildings serving as medical facilities specifically for the treatment of Tuberculosis, had steep roofs and high ceilings to allow sunlight to reach most of the space and kill as many germs as possible, becoming a scientific architectural method (Fezi 2020), as the legacy of this daylighting concept lives in the International Building Code (IBC).

Figure 5: Diagram of flat roof with occupiable space and diagram of a typical sanatorium. Source: (Garceau, 2022).

Other less successful alternatives included the use of skylights (Fig. 6) as this disturbed patients' experiencing direct sunlight from skylights as they laid down, as opposed to experiencing side light from clerestory (Fig. 7) windows (Adams and Burke 2006). Fig. 6 shows the evolution of top lighting with pandemics perhaps evolving into a light well strategy, which would maintain the benefits of top lighting while also being adapted to an office typology.

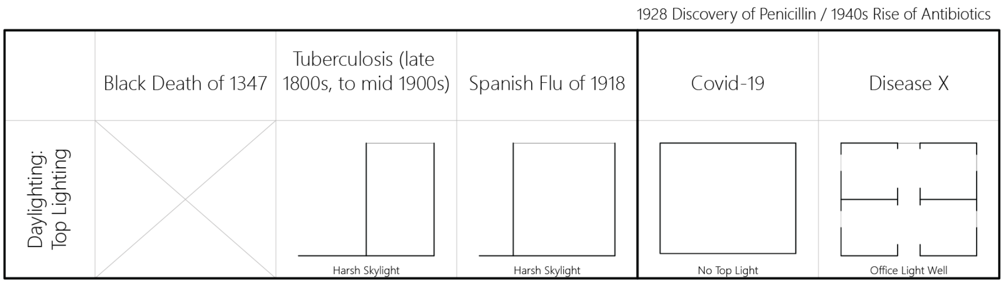

Figure 6: Diagram of steep roofs with popularization of clerestory and high ceilings. Source: (Garceau, 2022).

An example of an expansive light well exists in Bloomberg's London Headquarters which uses a central atrium light well (Fig. 7) alongside a skin framework that uses angled panels to maximize light while reducing direct sunlight glare and heat exposure (Foster + Partners 2017). Due to the building's large size, the addition of the atrium space allows the center of the building to be naturally daylit in addition to the building skin strategy. The orientation of the building is also a key component in daylighting, so the headquarters is oriented with the larger side of the floorplates facing the north and south directions, with the short ends of the building facing the east and west directions. This allows for a reduction of glare from the east and west directions while maximizing controlled exposure from the north and south. The light well utilizes high ceilings and additional windows to allow light to penetrate deep into the building, which was a strategy popularized in Tuberculosis sanatoriums (the idea of large expanses of glazing to allow for a maximum amount of daylighting). These daylighting principles can be applied to larger buildings through innovative methods to allow light to penetrate through the office skyscraper completely. Although this example constitutes a five-story building compared to an office skyscraper, the logic of including daylighting can be applied to this larger scale. One can see in Fig. 7 how the strategy of clerestory windows and side lighting from Tuberculosis and the Spanish Flu may have a modern component in the form of clerestory or atrium glazing.

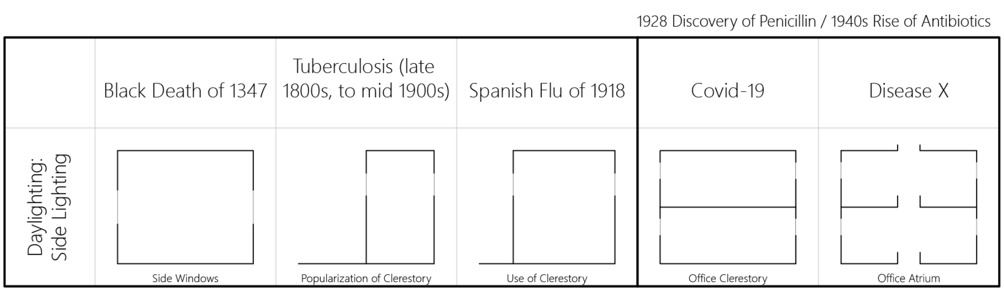

Figure 7: Diagram of an office light well and office atrium. Source: (Garceau, 2022).

2.4 Ventilation

During the Black Death of 1347, the prevailing understanding of how the disease spread was supported by the Miasma theory, which postulated that *bad air* caused disease (Karamanou et al. 2012). As a result, those that could, sought the thought to be purer air of the mountains (Campbell 2005). This same idea came back during Tuberculosis during the late 1800s, to mid-1900s. Before the arrival of antibiotics in 1944, the fight against Tuberculosis mostly involved an architectural response in the form of the rest cure, lasting until the beginning of the 20th century. Even in modern times, the regulation of airflow is important because "at the architectural scale, viruses can transmit in confined spaces not only by transmission but also by aerosol that can remain airborne for hours" (Fezi 2020). Modern ventilation systems can take this idea of fresh air as important to fighting disease (popularized during Tuberculosis) one step further. The ASHRAE 2014 report on Airborne Infectious Diseases mentions that in studies from 2012, “dilution ventilation can support pandemic management as an essential complement to social distancing” (Schoen et al. 2014). In addition to a medically supported solution of separation, proper ventilation can play an important role in mitigating the transmission of respiratory disease. However, the recirculation component of modern air conditioning systems may increase the transmission of respiratory diseases, such as the virus that causes COVID-19 (Fezi 2020).

A 2007 study measuring air-changes per hour (the amount of times air in a room is completely replenished) in hospitals comparing natural ventilation to mechanical ventilation found that the natural ventilation was more than two times as effective in reducing healthcare-associated infections within the hospital (Escombe et al. 2007). In this case, the natural ventilation involved opening doors and windows to the outside (Fig. 8). Even though this relates to a hospital, this concept can provide insight into the importance of natural ventilation in helping to combat disease in office. Thus, utilizing natural ventilation instead of mechanical systems, or perhaps a hybrid of the two, may help reduce the spread of respiratory viruses more than a mechanical system could alone.

Figure 8: Diagram of modern air conditioning and diagram of Escombe natural ventilation. Source: (Garceau, 2022).

3. RESULTS AND DISCUSSION

Looking at COVID-19 specifically, “the COVID-19 pandemic has revealed the weaknesses of our health systems that were unprepared to cope with a very large number of patients requiring respiratory support therapy in a short time frame” (Ciotti et al, 2020). Perhaps better preventative measures may have been able to lessen these numbers and result in a health system less ill-equipped. Architecture, designed in conjunction with mechanical systems, can provide for a healthier future through preventative means such as the use of adaptive architecture, daylighting strategies, and natural ventilation. One way this may be achieved is through balconies, occupiable roofs / terraces, and in-between transitional spaces. The research findings depict a loss of a balcony from the introduction of antibiotics (Fig. 9). The expansion of the balcony occurred during Tuberculosis so beds could fit outside to help with the ‘rest cure’. As the ‘rest cure’ started to lose popularity, during the Spanish Flu, there became a reduction of this outdoor space through the form of a balcony. During COVID-19, and with the introduction of HVAC systems, access to fresh air through balconies was not a focus.

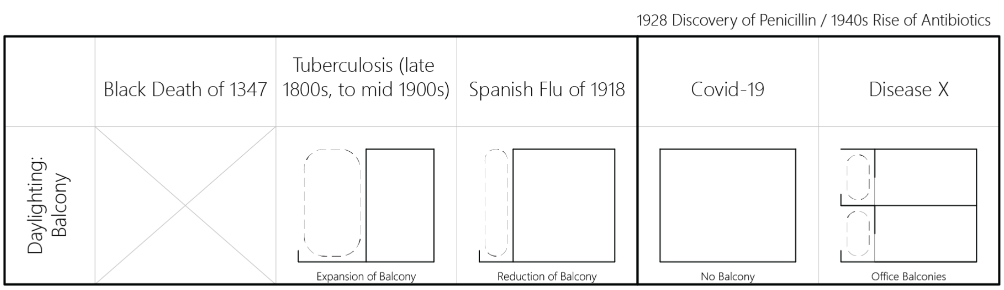

Figure 9: Diagram of balconies over time in relation to pandemics. Source: (Garceau, 2022).

Thus, a solution to architecturally impact Disease X may include a reintroduction of balconies in office space, to garner fresh air, and flexibility through multi-use of the space. Over time, one can examine how the status of roof occupancy has shifted throughout the pandemics (Fig. 10). During the Black Death, the shape of the roof relied mostly on the climate the building occupied. Meaning, the occupancy of the roof varied. However, during Tuberculosis, the popularity of the steep roof with high ceilings and balconies allowed for light to penetrate throughout the entire building and for people to occupy personal balconies to gain fresh air. As time passed, during the end of Tuberculosis and the rise of the Spanish Flu, the flat roof started to become more popular, allowing for people to start to occupy this ‘extra’ space. COVID-19 saw a decrease of the occupiable roof, and fresh air from the outside could be gained through means of HVAC systems alone. A way to pandemic-prepare buildings may include a reintroduction or integration of an occupiable rooftop and terrace, echoing the principles within Tuberculosis with an emphasis on fresh air, the importance of which is highlighted in the 2007 Escombe study.

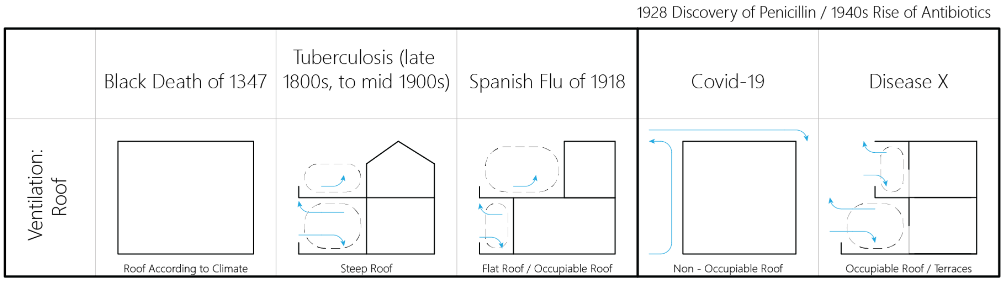

Figure 10: Diagram of roof occupancy over time in relation to pandemics. Source: (Garceau, 2022)

4. CONCLUSION

The four major respiratory pandemics: The Black Death, Tuberculosis, the Spanish Flu, and now COVID-19 have provided historical data as to how solutions such as adaptive architecture, daylighting, and ventilation have changed over time. These time-tested solutions provide a basis as to how to evaluate pandemic-proof commercial buildings of the future that act more proactively. To mitigate against the next respiratory pandemic, otherwise named as 'Disease X', architecture may incorporate these proactive building strategies discussed above and documented in Fig. 11, such as in-between transitional spaces, balconies, and outdoor terraces. Proper daylighting contributes to the overall health level of people in general. Light wells can penetrate light deep into the heart of an office and high ceilings allow for light to seep into a space. Mechanical systems alone may help spread disease, but the combination of mechanical systems with natural ventilation help mitigate the airborne spread. Ventilation may include engineering windows to open and shut based on temperature and/or air quality levels within the building, utilizing balconies and operable windows to the office space. Automated windows open and shut to regulate airflow and temperature within the building instead of the typical reliance on ductwork. In this manner, natural ventilation is engineered intentionally to reduce a spread of airborne disease. These strategies help to equip architecture against respiratory pandemics before they occur and create a more proactive architecture instead of a reactive one.

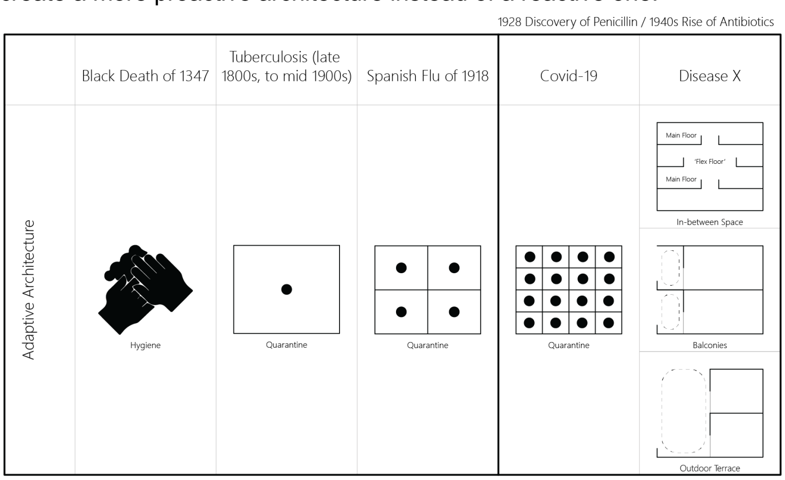

Figure 11: Diagram of research findings of adaptive architecture. Source: (Garceau, 2022).

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