

Don't throw stones!

A critical examination into
the development of London
glasshouses and their influence
on contemporary interior
architecture

India Lloyd

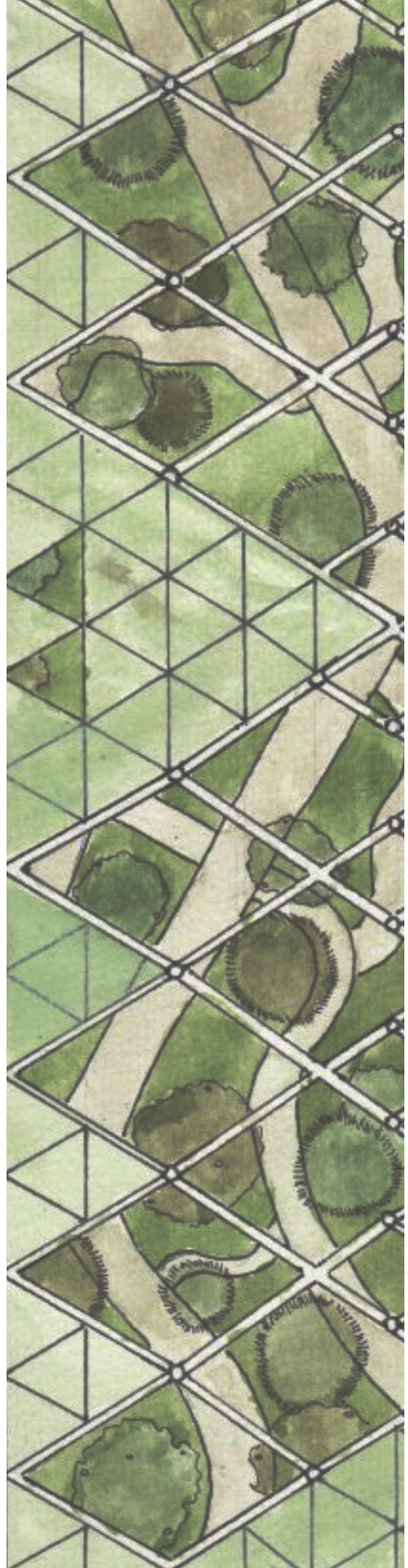




Figure 1. The Palm House structure protecting plants (Letek, M. (2019))

CONTEXT

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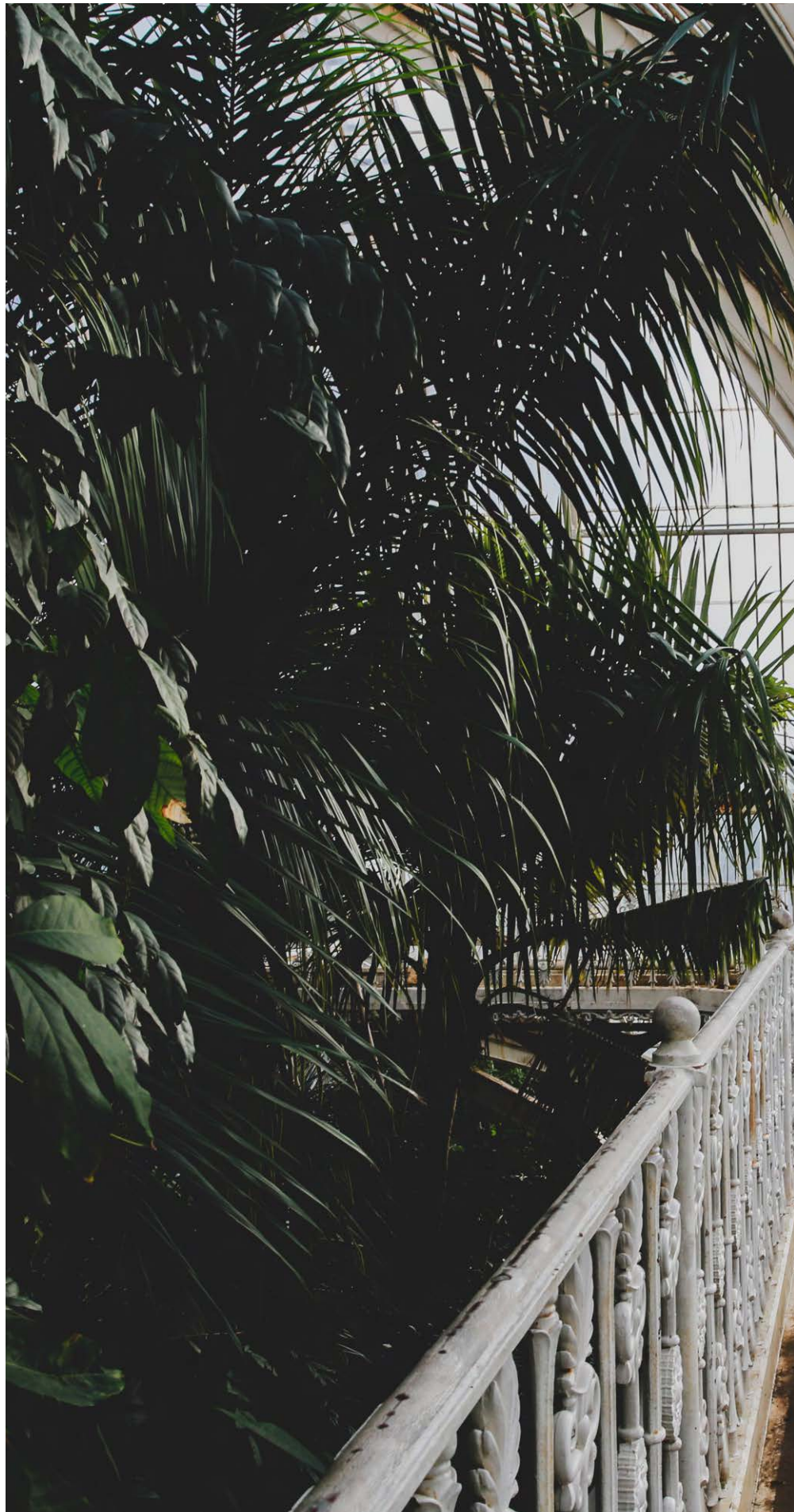


Figure 2. A glimpse of Palm House, Kew Gardens balcony (Mulrooney, S. (2020))



Public glasshouses are a spectacle and a sanctuary. The grand scale of these glass structures is always impressive, highlighting the engineering and the choice of materials. With all that glass they tend to look thin and delicate, but they are built to contain environments that protect living creatures of all kinds — vulnerable and special plants, wildlife, and human visitors (Figure 1). Ever since their invention, they have been linked with research, education and recreation (Guthrie et al., 1988).

In this paper we explore the evolution of the English glasshouse, focusing on four public glasshouses in and around London. These are the Palm House, at Royal Botanic Gardens in Kew, Barbican Conservatory, Princess of Wales Conservatory (also at Royal Botanic Gardens) and Crossrail Place Roof Garden (Figure 2). A focus on London based public glasshouses has been instigated due to their rich cultural and scientific implications, making noticeable impacts on individuals lives, human knowledge and notions towards modern day interior architecture. Also, it's possible to visit them all in a weekend trip! By looking at glasshouses constructed from 1848 to 2015 we can trace the development of materials, technology and therefore design, assessing any adaptations in purpose or function. I will also consider the influence of the glasshouse as a concept, and these four glasshouses specifically, on contemporary architecture and interior design. We will look to the past to determine why a glasshouse might be built today and what it might contribute to society.

Front Cover. The Crossrail Place Roof Gardens Floorplan (Author's own drawing)



Figure 3. Cambridge Botanical Glasshouse (Bach , F. (2012)



Figure 4. An example of a garden conservatory (Warren, C. (2019)

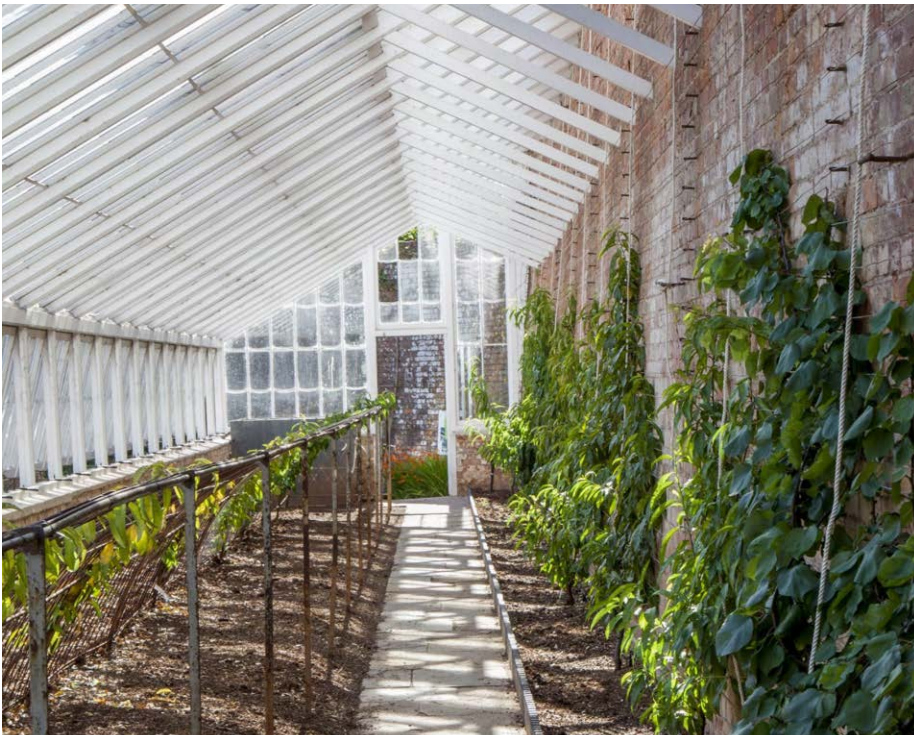


Figure 5. An example of an orangery (Magerus, M. (n.d.)



Figure 6. An example of a greenhouse (Zanda (2018)



WHAT IS A GLASSHOUSE?

It will be useful to begin by defining the different sorts of glass structures.

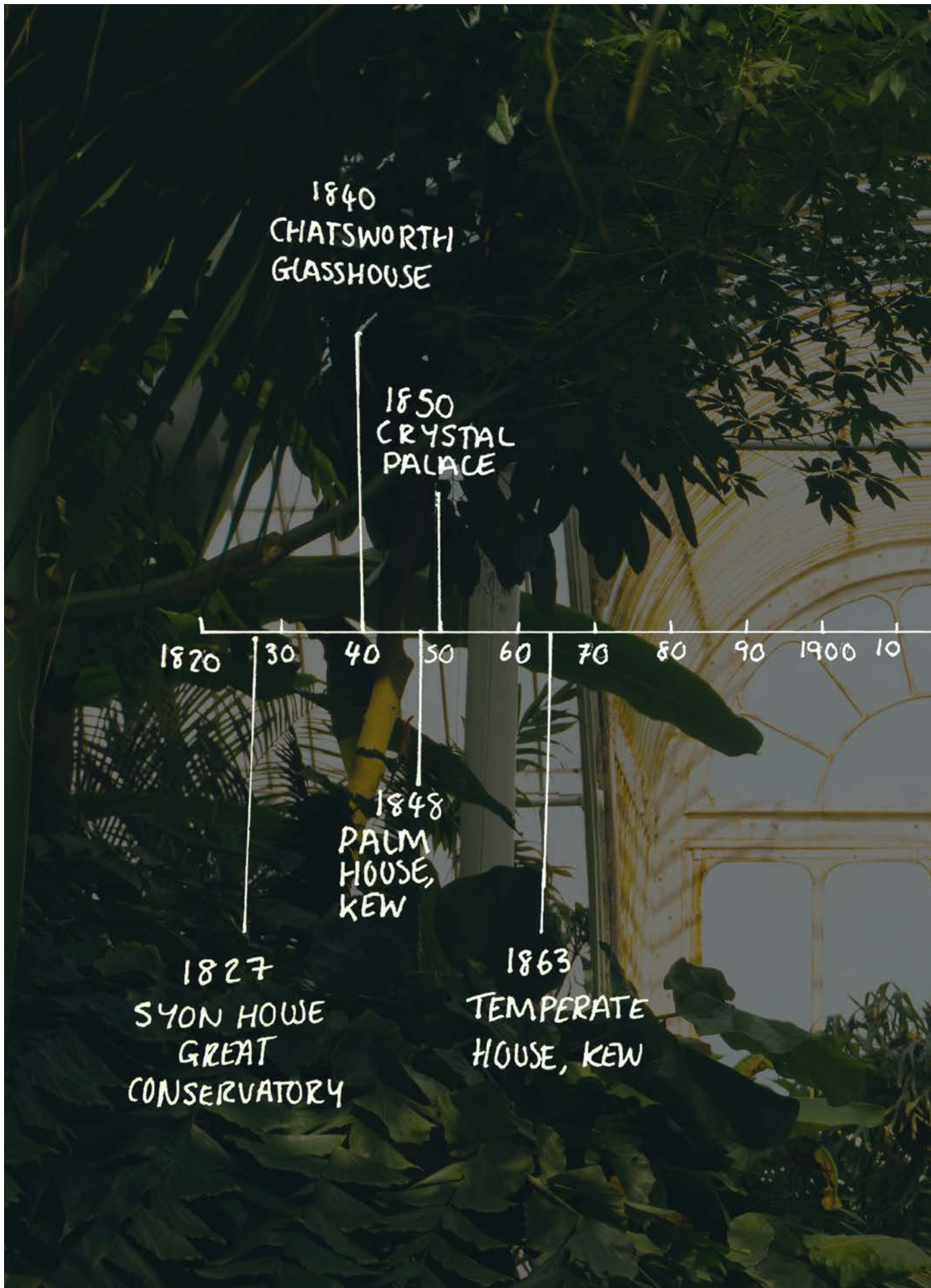
A glasshouse is a free-standing glass structure (see below for greenhouse, its smaller sibling), most often built to house tropical plants from warmer climates. Historically, a glasshouse was a mark of wealth and status, because they were expensive to build and to maintain, and so was often constructed as part of a stately home or an institution (Figure 3).

A conservatory is a glass room often connected to a private house and designed for views of the outside, to house plants from warmer climates and to be used as an extra living space (Figure 4).

An orangery is a tall south-facing glass structure, attached to a brick wall to the north, which houses citrus fruits in the winter (Figure 5).

A greenhouse is a free-standing glass structure whose main purpose is to grow plants for the household. Unlike the much larger glasshouse, a greenhouse was affordable for the middle classes, who often placed one at the end of the garden (Figure 6). (Neptune, 2022)

The common theme between all of these structural variations is apparent, letting light and nature into our daily lives.



TIMELINE OF IMPORTANT BRITISH GLASSHOUSES (Figure 7)



Figure 7. A timeline of important British glasshouses around London (Young, J. (2018))

A GLANCE AT FOUR
PUBLIC GLASSHOUSES





Figure 8. A glance at The Palm House, Kew gardens Front door (Miles, L. (2018)



Figure 9. Palm House bubble-like form (Avis-Riordan, Katie (2019))

PALM HOUSE, ROYAL BOTANIC GARDENS

When the Palm House was completed it was the largest glasshouse in the world (figure 8). The design was groundbreaking: the use of a new material, wrought iron, allowed for larger panes of glass, which let maximum sunlight into the house. Palm House was soon overtaken in size by the Temperate House (also at Royal Botanic Gardens), but it had already made its mark having inspired the Crystal Palace (Lynden, 2021), which was built on the outskirts of London by Joseph Paxton for the Great Exhibition of 1851. Though Crystal Palace is no longer standing, it is arguably one of the best-known public glasshouses in history.



Figure 10. Double height ceilings (Johnson, C. (2022))



Figure 11. wrought iron structure (Cadman, S. (2008))

Architect: Decimus Burton

Date of completion: 1848

Purpose: scientific research

Design attributes: double-height ceiling allowing for tall forest trees, semi-circular walls creating a bubble-like form (Figure 9) (Figure 10).

Materials: wrought iron and tinted green sheet glass (figure 11).



Figure 12. The Conservatory on the roof of the Barbican Centre (Bradley, D. (2018))

BARBICAN CONSERVATORY

The Barbican Estate was built in the 1960s to repopulate an area of London which had been destroyed in the Second World War. The Conservatory was added later and was designed as an indoor oasis for the general public and also to camouflage the fly tower (Figure 12). Due to low footfall in the early years, the space was turned into a venue for private hire and is now only open to the public on Sunday afternoons (Ankhesenra, 2017). The Brutalist design of the Barbican Estate makes this an interesting glasshouse: the functional, 'ugly' and modern aesthetic of the concrete contrasts with the organic, living forms of the plants inside (Figure 13). The plants grow over and along the concrete architecture, like an abandoned city that has been taken over by nature.



Figure 13. The functional, brutal and modern aesthetic of the concrete contrasts with the organic plants (Martin, R. (2019))

Architects: Chamberlin, Powell and Bon

Date of completion: 1982

Purpose: public use and education

Design attributes: wrapped around brutalist architecture, plants climbing up the Barbican Centre tower (Figure 14)

Materials: concrete, steel and glass

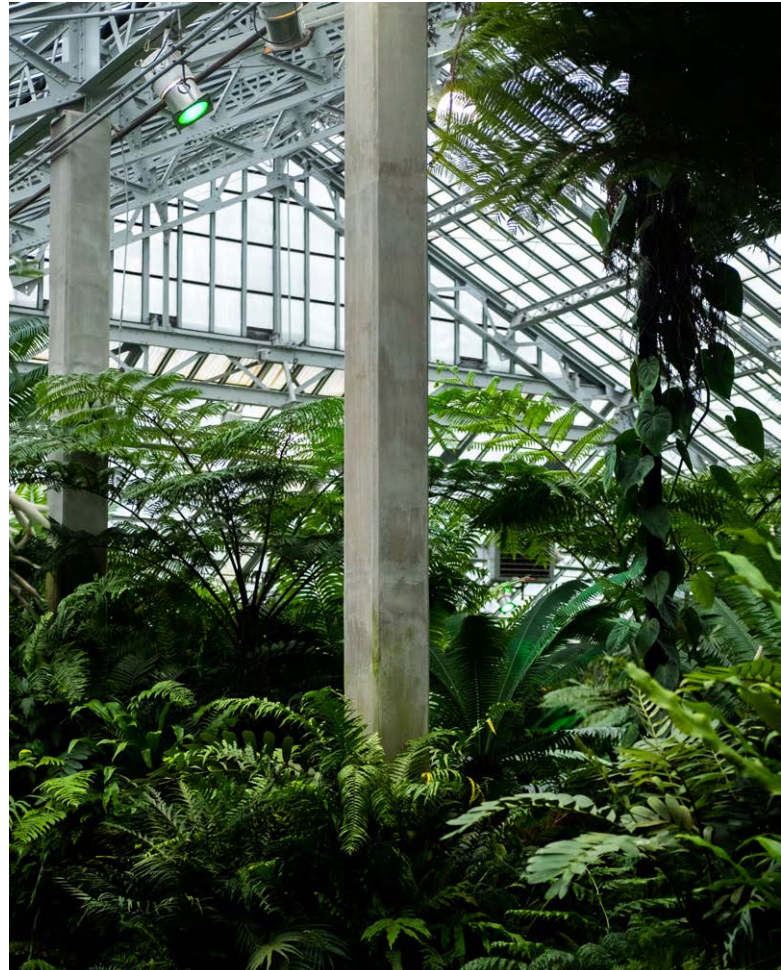


Figure 14. Plants surrounding the concrete columns (Betts, A. (2019))



Figure 15. Princess Of Wales Conservatory, Kew Gardens (n.a (2022))

PRINCESS OF WALES CONSERVATORY, ROYAL BOTANIC GARDENS

This is currently the biggest glasshouse at Royal Botanic Gardens and houses ten different climatic zones. This allows for research into the plants, insects and animals of several different ecosystems. The glasshouse has a distinctly contemporary design, abandoning the curves of the Palm House or the height of the Temperate House and instead using repeated triangular angles and a chunky framework of I beams (Figure 15)(Figure 16). A priority of the design was that the building was energy efficient and low-cost. Could this be the future direction of glasshouses?



Figure 16. Inside main section of Princess of Wales Conservatory (Case, D. (2014)



Figure 17. Triangular roof over the Giant Waterlilies (Gardens , K. (2018)

Architect: Gordon Wilson

Date of completion: 1986

Purpose: scientific research, education and public recreation

Design attributes: staggered roof heights, triangular motif, very large floor plan (Figure 17)

Materials: steel, roughcast glass (interior) and clear glass (external)

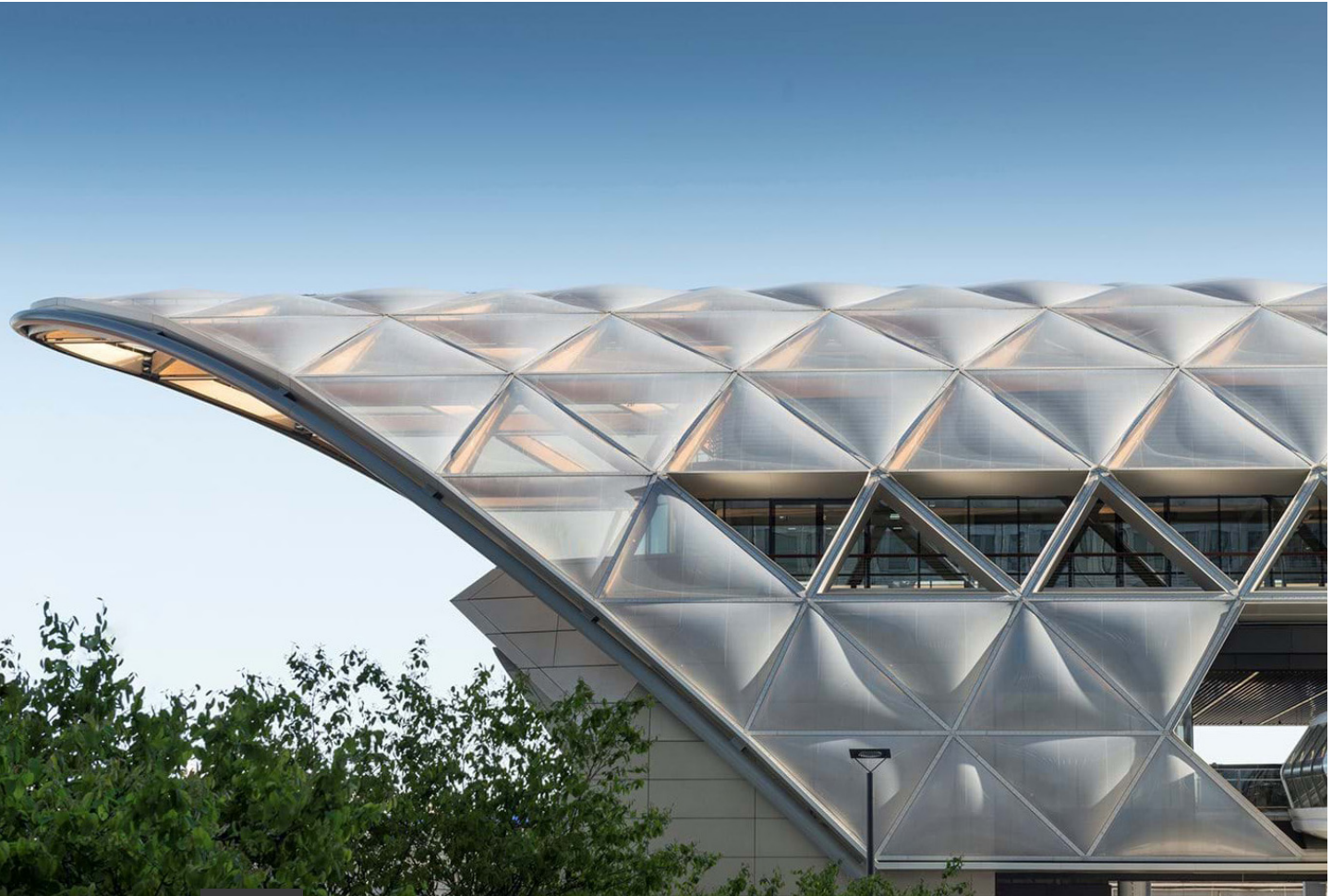


Figure 18. Crossrail side view (Young, 2018)

CROSSRAIL PLACE ROOF GARDEN

Crossrail Place Roof Garden is unusual for two reasons: 1. It is a rooftop structure (Figure 18); 2. It uses ETFE (a type of plastic) rather than glass. A modernisation of building technique influenced by new material possibilities. This glasshouse is situated in the North Dock of Canary Wharf, beside the River Thames (Figure 19). It is 300m long, its curved roof has a repeated triangular pattern, and it offers 360-degree views. The main purpose of the space is as a public walkway, providing people with a place to relax.



Figure 19. Crossrail Place Roof Garden (Canary Wharf Group, n.a)



Figure 20. Curved roof (Carstairs, n.a)

Architects: Foster & Partners

Date of completion: 2015

Purpose: public walkway above train station

Design attributes: rooftop structure with curved, triangle-motif dome (Figure 20)

Materials: glulam timber, steel and ETFE (ethylene tetrafluoroethylene)

Reference : www.example.com

WHAT CAN WE LEARN FROM THESE FOUR CASE STUDIES?

As technology developed in the 1800s, materials used in the construction of glasshouses moved from timber to iron. This allowed the scale of the Victorian glasshouse to become much more ambitious, as the stronger metal could support larger panes of glass (Figure 21). Then, with the Palm House, we see the first example of wrought iron. Both the Barbican Conservatory and Princess of Wales Conservatory (both constructed in the 1980s) use a steel frame and in the most recent glasshouse we see a return to the use of timber, because of the introduction of lighter, cheaper ETFE instead of glass.

Many glasshouses were built to support scientific research into foreign plants. Alongside this, the general public developed a growing interest in the glasshouses, which encouraged scientific institutions such as Royal Botanic Gardens to gradually open up their doors to the public. There is also now a strong and diverse online offering from Kew Gardens featuring virtual tours, exhibitions and talks that delve into the rich history and educate on discoveries made (Gardens, 2020). More recently, the Princess of Wales Conservatory was designed with public entry in mind and some public glasshouses are now built with the aspiration to let the public relax and escape to a calming space within the city. These are often called green spaces and are becoming more popular in city centres. There is often a desire to bring a diversity of visitors into a commercial space that might include shops, restaurants or retail spaces alongside a glasshouse or green space. The spectacle and attraction of glasshouses has continued.

Figure 21. Workers outside the Palm House (Gardens, 1857)





Figure 22. The Barbican brutalist architecture covered in plants (Author's own drawing)

These four case studies follow a change in thinking about the use of land in urban environments. In areas such as London there is generally now a shortage of available space for architectural development. The Palm House, and the new Princess of Wales Conservatory mark era where vast scale was possible. The large footprint would be a restrictive consideration for a modern day inner-city glasshouse. Comparatively, rooftop and integrated glasshouses, such as the Barbican Conservatory or the Crossrail Place Roof Garden, show a creative response to the shortage of land in a city (Figure 22).

THE ADAPTATION OF GLASSHOUSES

A large number of Victorian glasshouses were built to house tropical plants that explorers brought back from the territories that England had colonised. Early examples of this are Syon House Great Conservatory and Palm House, both situated in what would have been the countryside then, just outside London. Scientific research flourished during the Victorian era: Royal Botanic Gardens (including the Palm House) was founded to house and catalogue plants and flowers from around the globe, to learn how to protect them in the future, and to help with the discovery of new medicines (Avis-Riordan, 2019). Originally these large glasshouses were not for public access but there was growing public interest in horticulture. The Palm House eventually opened up fully to the public in 1921, just after the First World War (Port & Yates, 1978). Crystal Palace was in some ways a response to the public's growing interest in glasshouses. Its purpose was to hold the Great Exhibition in 1851 which was open to the public; it continued as a public venue but did not house plants until it was rebuilt in 1854 (Figure 23).

A look at the timeline reveals a large gap of over 100 years during which no notable glasshouses were built. During the two World Wars priorities were elsewhere: engineers and architects were fighting or using their skills as part of the war effort, funds were in short supply, and travel overseas to collect the tropical plants ground to a halt. Glasshouses were re-used during this difficult period to grow food for the nation (Bewley, 1956). In the mid-twentieth century, following the wars, the focus was on redesigning and the reconstruction of London.

As political stability and prosperity returned, glasshouses came back in fashion. Glasshouses turned less into places of science and more for the general public's recreation and tourism. The country had just gone through a devastating time, so lifting public morale was very important. The Princess of Wales Conservatory was designed with both public and scientific use in mind, allowing education and learning for all ages to take place.

Some have questioned why the Princess of Wales Conservatory was not built like the Palm House, to be grand and lustrous (Lambert and Sarkar, 1991). The aim for the Princess of Wales Conservatory was for it to have a large floor plan but maintain a lower height — the Palm House is for tropical trees, whereas the Conservatory was designed to house smaller plants. The Princess of Wales allows for ten different tropical environments to live under the same room, which was something that had never been done before (Lambert & Sarkar, 1991) (Figure 24). Not only did they want the experience for the public to be like no other, the purpose of building The Princess of Wales was to be environmentally friendly, with low costs and low emissions, which did not cross architects' minds in the mid 1800s. An example of the spirit of the times imparting environmental values on architectural building practices.



Figure 23. An interior view of the rebuilt Crystal Palace (Historic England Archive, 2021)



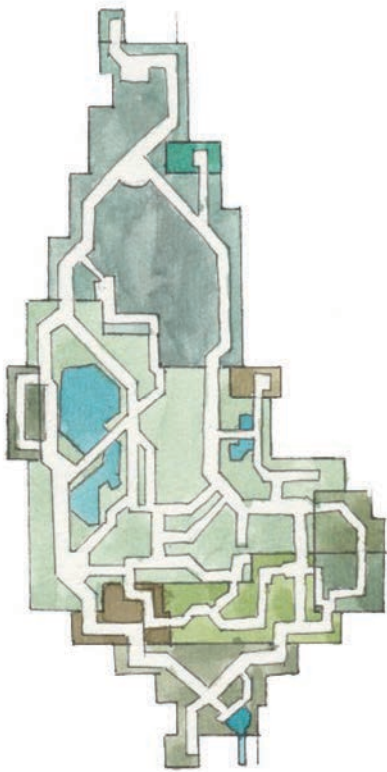


Figure 24. Princess of Wales Conservatory floor plan (Author's own drawing)



Figure 25. Palm House Spiral Staircase (Johnson, 2022)

With less of a focus on acquiring new scientific information on plants and a push for health and wellbeing within cities, glasshouses are increasingly popular as places to relax. These 'green spaces' are dotted around cities and encourage people in densely populated areas to spend time in nature without travelling (Stigsdotter, 2005). At Crossrail Place they incorporated a 300m long botanical garden on the roof of the Canary Wharf tube station, combining commercial and community spaces. This not only is great for the public but draws in commercial business as well, as people have to walk past shops and restaurants to get up to the roof garden.



Botanical gardens and glasshouses have always been admired and desirable spaces, as they previously signified wealth and high social status (Hudson, 2019), which can sometimes be an underlying aspect of them today. These huge glasshouses are not cheap to keep running. The Palm House has had to have constant maintenance done to it throughout the years to keep it efficiently working (Figure 25); opening the houses up to the public was one way of generating money (from ticket sales) towards maintenance. These environments are also popular places for weddings and parties; even though the older glasshouses were not made for this purpose, ones such as the Barbican Conservatory were designed to house events, this is very much a modern use for glasshouses (Ankhesenra, 2017) (Figure 26).



Figure 26. The Barbican boasts one of the most unusual venues (Photography, n.d.)

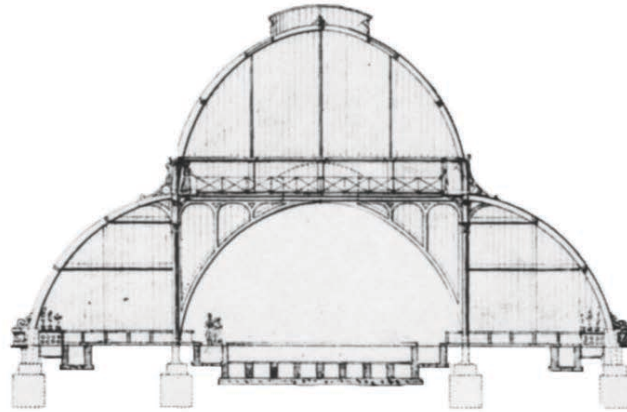


Figure 27. Transverse section of Turner's design (Richard Turner)

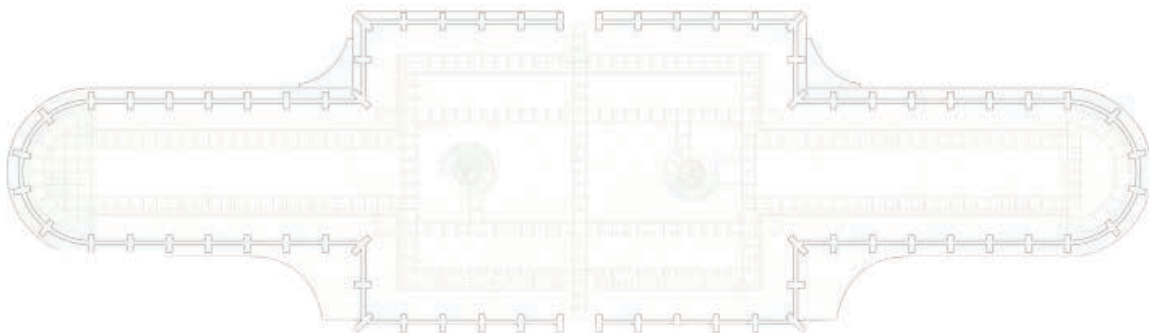


Figure 28. Section and floor plan of Palm House Kew Gardens (Harskamp, 2013)

THE EVOLVING DESIGN OF GLASSHOUSES

In the early 1800s architects had little experience working on glasshouses, which meant there was often a lot of experimenting with materials and structure. When working on The Palm House, the architect Decimus Burton and engineer Richard Turner went back and forth, debating what would be the best design (Desmond, 1972). During the industrial revolution steel and iron were commonly used in architecture because they were longer lasting than wood, but the use of wrought iron in the Palm House made the design process a lot longer as not many architects or engineers had worked with it on this scale. One useful influence on the technical aspects was the design of boats; this is why the Palm House looks like the hull of a ship (The Palm House at Kew Gardens, 2014) (Figure 27)(Figure 28).

Building glasshouses on the scale of Palm House had only been done once before at Chatsworth House, where Joseph Paxton completed a glasshouse in 1840. (Decimus Burton was said to have had a part in the making of Chatsworth, but the role is unknown. In turn, the Palm House had a part in inspiring the world-famous Crystal Palace which is a key historical structure within the evolution of the glasshouse due to the scale of the project (Addis, 2006).

After the two world wars, steel became more popular in the construction of glasshouses than iron due to its strength and resistance to rust (Dyke, 2004), an important factor because of the natural humidity from all the plants and because glasshouses often have internal water spray systems. Steel is an alloy made up of iron and carbon, which also makes it easier to bend. The Barbican Conservatory and The Princess of Wales Conservatory are both made of steel. The latter was designed with strict environmental guidelines; steel can be recycled over and over again without losing its structural properties (Kathy, 2020).

Glasshouses became less lavish and decorative over time, moving more towards functional environments for housing plants and attracting visitors (Figure 29). This shift in design approach made building these structures more efficient and mitigates the high costs of ongoing maintenance that previous glasshouses suffered from.

Figure 29. A cast iron plant found at kew gardens (Author's own drawing)





Figure 30. ETFE roof at Roof garden, Canary Wharf Crossrail Station, Crossrail Place (Lee, 2015)

Crossrail Place was an interesting case study and in some ways does not fit the category of 'glasshouse' because of the lack of glass within the structure (Figure 30). At first sight you might assume the roof of the multi-purpose commercial building was glass but it is made of ethylene tetrafluoroethylene (ETFE), a type of fluorine-based plastic. This material is rising in popularity as an alternative to glass, most famously in the design of the Eden Project in Cornwall. ETFE was developed in America in the 1970s by a company called Dupont (Lynch, 2019). The material took some time to be incorporated in European architecture but has now become very popular in modern architecture, especially in glasshouses, due to the ability to regulate environmental conditions through UV transparency (Durstun & Robinson, 2016). Whereas the green stained glass used in the Palm House became less effective over time because of the build-up of dust and soot (Desmond, 1972), ETFE has a low friction coefficient, meaning dust does not stick to the windows. Solar conditions can also be controlled by printing patterns and layers on the plastic (Lynch, 2019). Due to the light weight of the material it is easy to transport and install making it a sustainable choice for the modern advancement of the glasshouse concept.



Figure 31. Climb the ornate spiral staircase inside the Palm House to see the top of the trees (David, 2015)



Figure 32. Concrete jungle (Matcha, 2019)

A common design element in glasshouses generally, and in these particular case studies, is openness and space. There is a sense that they bring the spaciousness of the outside inside. High ceilings allow tall trees and plants to grow far above the average domestic first-floor height (Figure 31). The Palm House, The Princess of Wales Conservatory and the Crossrail Place Roof Garden have had their plants planted in specific organised ways, with set beds and paths for visitors to follow. Whereas, the Barbican Conservatory has gone for a very different approach, allowing plants to grow everywhere, even up the original fly tower and in the balconies. This abandonment could be described as a dystopia within a utopia, or a true jungle with the 'concrete jungle' of the Barbican Estate (Dean, 2022) (Figure 32).

GLASSHOUSES AND THE ENVIRONMENT

With growing populations and land under increasing pressure, it has become more common for public glasshouses and conservatories to be built on top of commercial buildings (Pouya, 2019). Some mini glasshouse structures are squeezed in between neighbouring skyscrapers, like in East London where the company Hartley Botanic has built a black glasshouse to try encourage horticulture back into everyday life; others are built on top of residential buildings, like The Culpeper Rooftop which is a glasshouse with a bar and garden for the public to enjoy.



Harnessing the sun's heat and light is a crucial factor in the design of glasshouses as it is what keeps non-native plants alive in the English climate. The Princess of Wales Conservatory included solar panels in its design, harvesting the sun's energy for use across the Gardens instead of just for the plants' photosynthesis (Figure 33). Urban glasshouses can also help combat air pollution because of plants' ability to absorb carbon dioxide and release clean oxygen. Cities such as London suffer from the emissions of factories, cars, public transport, commercial and private properties, and various agreements and strategies have been put in place to combat this. Starting in 2008 low emission zones were introduced through the centre of London to cut down carbon dioxide levels. Glasshouses and green spaces can be part of the broader efforts to reduce global warming.



Figure 33. Princess of Wales Conservatory (Mcrobb, n.d.)



(Figure 34) drawing of Palm House interior (Author's own drawing)

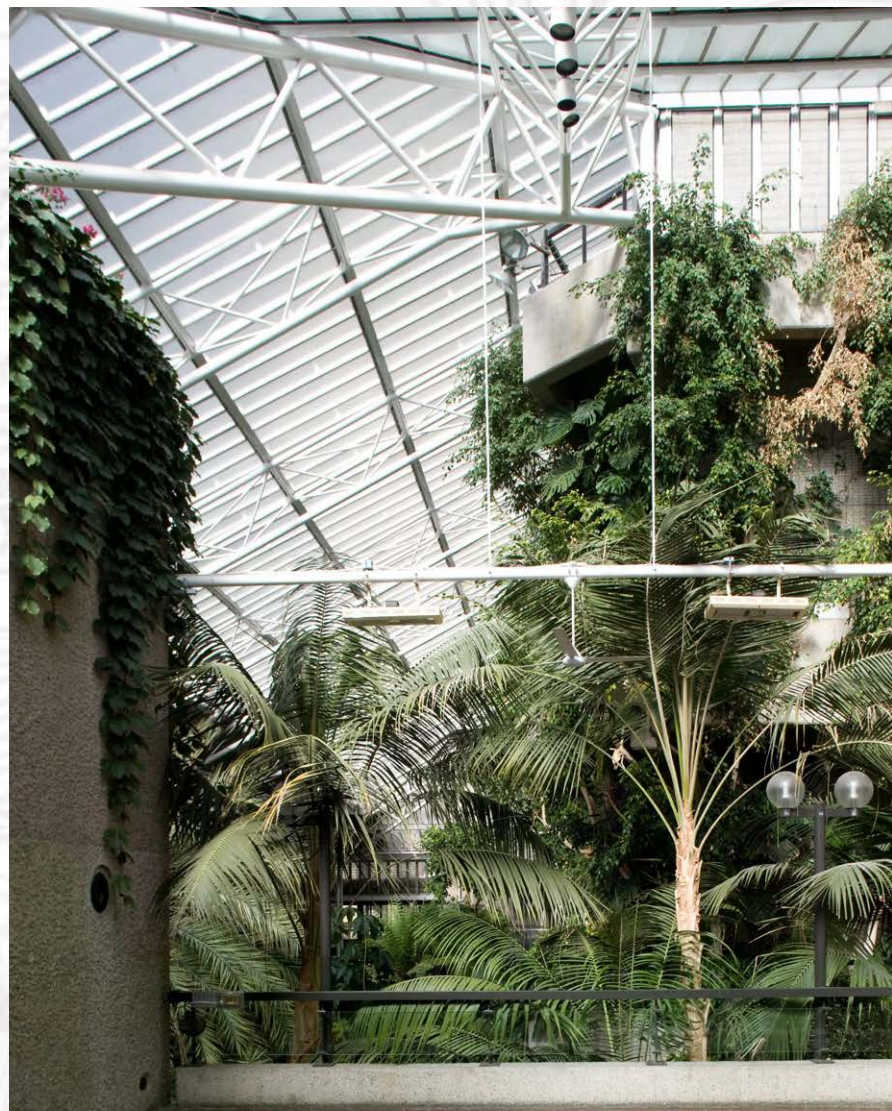


Figure 35. The Barbican has 1,500 special tropical plant species Hayes, L. (n.d.)

Some historical glasshouses are now home to endangered plants and some plants that are sadly extinct in the wild. For example, the *Encephalartos woodii* was brought to the Palm House in 1905 and now no longer exists in the wild (Guthrie et al., 1988) (Figure 34). Glasshouses can house thousands of plants at once, acting as a sort of catalogue or 'living library' of many species: the Barbican has 1,500 special tropical plant species (England, 2022)(Figure 35). What began as a general scientific curiosity now serves more urgent environmental concerns for biodiversity. If voyagers had not brought exotic plants back to England would they exist here now? Would these plants be completely extinct if research-focused glasshouses did not exist?



Just as glasshouses can help with the health of the planet, they can also help with the health of its human citizens. In recent years the strive for better health and mental health has become a topic of interest for city planners. With 1 in 4 people experiencing mental disorders in the UK each year there is a fight to improve this pressing issue (Mind, 2017). Green spaces within cities have been shown to contribute to citizens' wellbeing by reducing levels of stress, anxiety and depression (Admin, 2022). Not only do they help with mental health but physical health too; a Japanese study shows that lowering people's pulse rates and blood pressure can be done by simply walking through forest environments (Park, 2010). As cities become more urbanised and take us away from our true nature, interior architecture can adapt, recognising the powerful positive impacts of nature on the human mind. Bringing green spaces back into the forefront of daily existence.

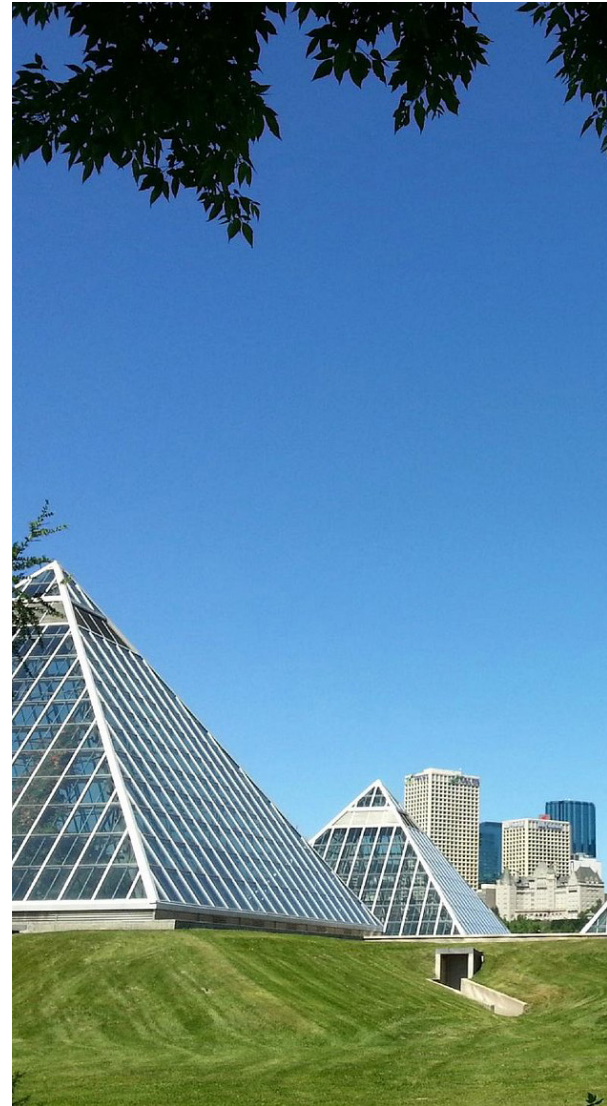


Figure 36. The Barbican has 1,500 special tropical plant species
Hayes, L. (n.d.)



Figure 37. Farnsworth House, designed by Ludwig Mies van der (RoheSchwartz, 2019)

THE IMPACT OF GLASSHOUSES ON CONTEMPORARY INTERIOR ARCHITECTURE

Glasshouses have been evolving for 100 years throughout the world with impressive glasshouses like Muttart Conservatory, Alberta, Canada, The Gardens by the Bay, Singapore and the Botanical Garden of Curitiba, Brazil (Figure 36). The evolving glasshouse design has not only inspired newer generations of glasshouse but has clearly influenced modern-day architecture and interior design. One modernist example is Mies Van Der Rohe's take on a glass house, The Farnsworth House, which is famous for its glass walls and minimalist interiors (Figure 37). It is a very simplistic single-storey structure and allows views from every angle of the house out into nature. Contemporary domestic residences with glass walls (Martin, 2017) maximise light and enjoy views of the surrounding landscape but suffer from a lack of privacy. We will likely continue to explore with the degree of the barrier we create between ourselves, living inside, and the outside world.



Figure 38. TP Bennett living wall (Jordahn, 2021)

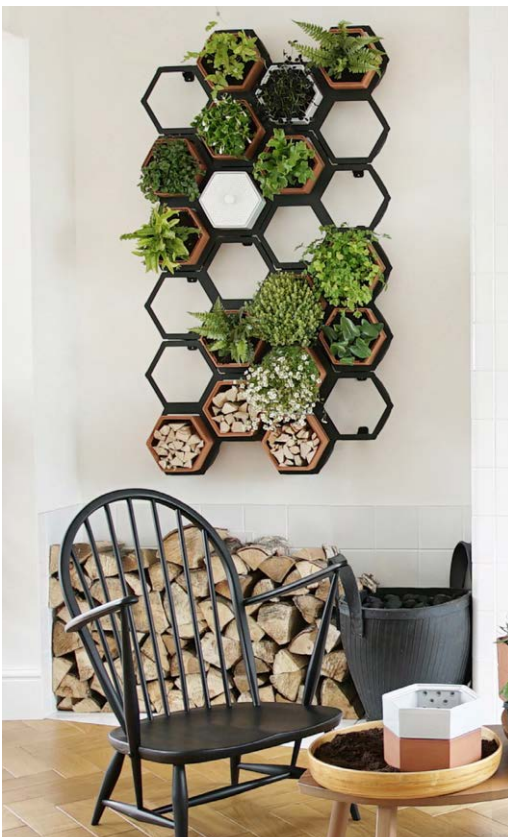


Figure 39. Horticus creates modular indoor living wall (Dezeen, 2020)

Interior architecture has become influenced by botanical glasshouses by not only using potted plants indoors to create a natural aesthetic but to have them growing in and on the building. Windmill Green, the office building in Manchester is a great example of an interior living wall breaking through the large glass facade (Jordahn, 2021)(Figure 38); this and living wall fixtures are a great way to bring plants into interiors (Staff, 2020)(Figure 39). It allows plants to be integrated into limited interior space and gives a pinch of horticultural glasshouse feel to a space. The original glasshouses sought botanical wonders from all over the world, acting as a foundation to inspire and slowly cultivate a more general and cultural appreciation of plants within the interior space.



GLASSHOUSES OF THE FUTURE

Glasshouses have evolved a lot since the Palm House in 1848 and the change can be seen in modern-day examples (Figure 40). The glasshouses of the future will continue to surprise us as new technology and materials are developed. It is clear that the general public has a huge interest in such spaces, with 1/3 of a million people visiting the Princess of Wales Conservatory in the first month of its opening (Sarkar et al., 1992). As cities become more densely populated, the affordability, sustainability and transportability of glass constructs could shine a new lease of life onto inner-city rooftops.



Figure 40. The Gardens by the Bay, Singapore (Sheppard, 2016)

The Coronavirus pandemic prevented travel abroad. During this time, visits to public gardens increased and day trips to big tropical glasshouses will have been seen as an exciting alternative. At the moment, the high price of oil, electricity and gas due to many factors in 2022 has left households struggling to sustain themselves. This has also increased interest in local destinations. As we step into an uncertain future, we may find local destinations of beauty such as glasshouses are fully appreciated for their psychological benefits, accessibility and being climate friendly alternatives to overseas travel.



Figure 41. Walking Through Sky Gardens
(Keyzor,n.d.)



Figure 42. Botanical garden, Curitiba, Parana State, Brazil (Obaqueta, n.d.)



The historic accomplishments and landmark nature of glasshouses have served to inspire and educate generations. They have contributed to an increasing interest and sentiment towards exotic plant species and a desire to embrace the outdoors, indoors. The glasshouse is the perfect showcase of the bold and beautiful, inspiring individuals to collect and appreciate such plants in their homes. In turn, interior architecture has evolved with this appreciation, moving towards spaces that compliment and embrace the flow of light and rhythm of nature.

In the modern day, many of us gravitate towards living in cities for both social and career opportunities. These environments are rich and evolving displays of interior architecture. However, they are often a victim of their own urbanisation and a connection with nature can be lost. Glasshouses and their influences on our interior spaces serve to reinvigorate these environments with natural life.

It is certainly likely that these spaces will continue to focus on the benefits of architecturally curated green spaces and on mental and physical health going forward. The concept of a glasshouse can go beyond the cultivation of plants, we are living organisms and require sun in many ways that are shared with our plant counterparts. Interior architecture has the power to transform any space, shifting the way people think, feel and relax into their surroundings. Glasshouses serve to challenge us to reduce the barrier between the inside and the outside, fully connecting us with our natural origins.

As we step into the future, we will likely be faced with uncertainty but also a continued love of nature. As they become more densely populated, cities will need to explore new and innovative ways of utilising land and repurposing space. Glasshouses have allowed for great advancements in the sustainability, affordability and transportability of transparent structures. As rooftops are readily available through densely populated areas, it is likely interior architecture can be used to adapt these unshaded and light-rich environments (Figure 41) into safe escapes from increasingly modern and technology driven lifestyles.

Glasshouses allowed us to harness environmental conditions and create temperatures well suited for plants (Figure 42). As climate becomes an increasingly important part of our future we may see a resurgence of glasshouses in the form of modern and innovative transparent structures, with temperature control and sustainability becoming even more central aspects of interior architecture.

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