Contemporary Curtain Wall **Architecture**

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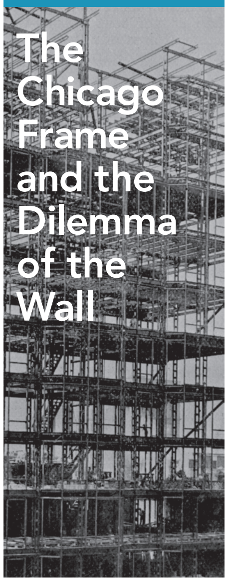

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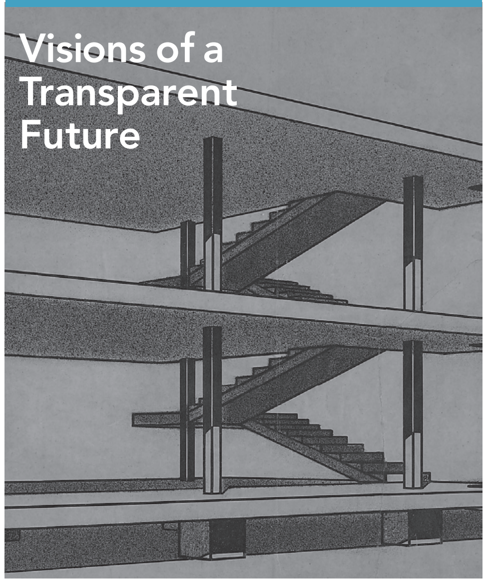

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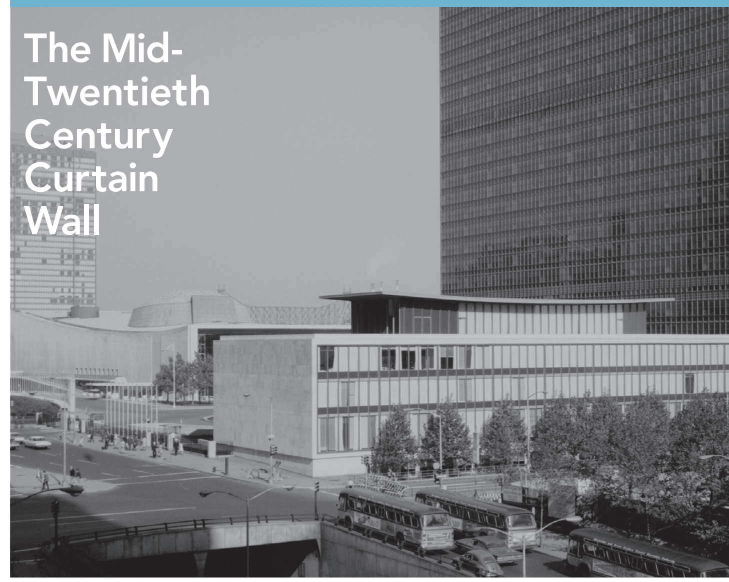

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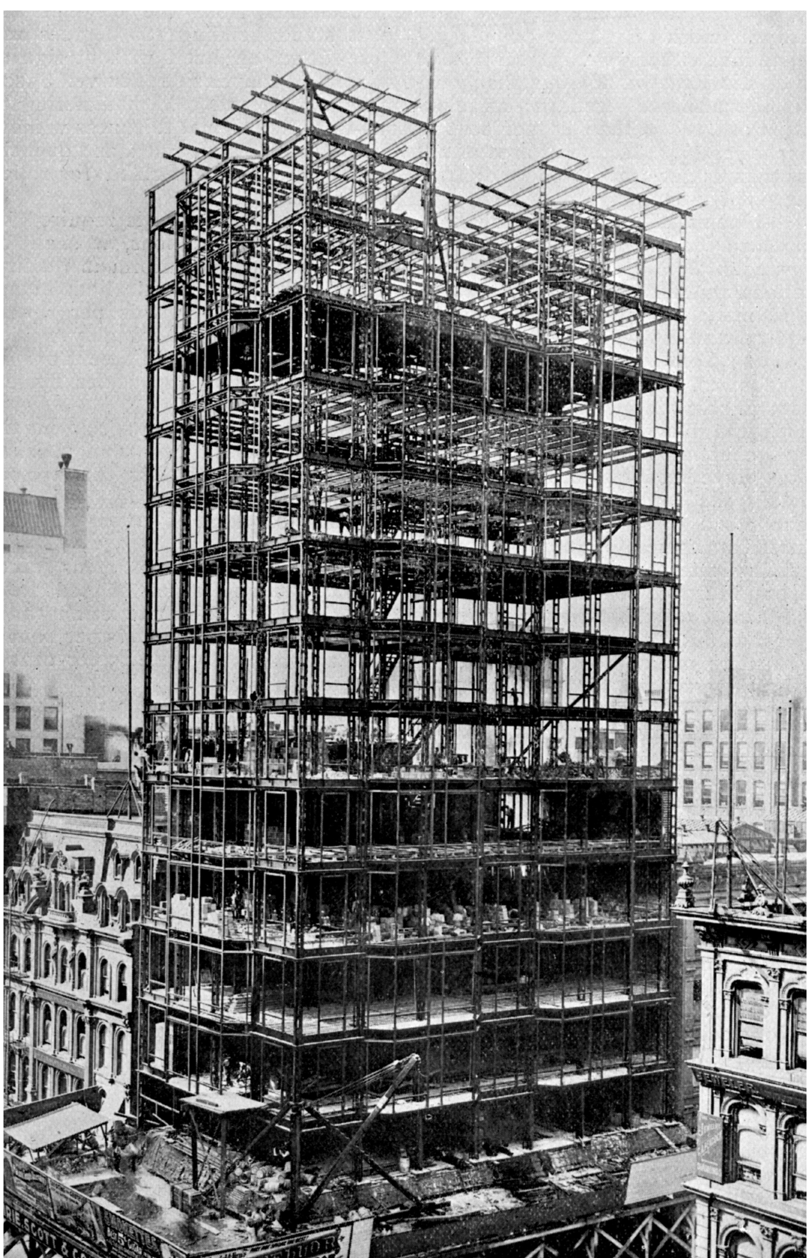
New Directions and Priorities

1

The Chicago Frame and the Dilemma of the Wall



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1.1
Construction of the Reliance Building's structural frame, August 1894

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Leiter Building I, Chicago, Illinois, William LeBaron Jenney, 1879

1.3
Ludington Building, Chicago, Illinois, William LeBaron Jenney, 1891

In his 1956 essay "Chicago Frame," Colin Rowe characterizes the frame structure as a universal theme of mid-twentieth-century architecture, proposing it to be the "essence of modern architecture."[1] The late-nineteenth-century development of the frame structure—using columns and beams of concrete, iron, and steel as a replacement for traditional solid-masonry load-bearing walls—marked a major transformation in architectural design and construction, exerting substantial influence over the commercial and institutional architecture of cities, particularly Chicago, where, as suggested by the title of Rowe's essay, architects and clients embraced the new technology early on. From its experimental manifestations in the nineteenth century to its proliferation through the present day, the skeleton-frame structure was significant not only for its technical achievements and widespread dissemination but also as a catalyst for new conceptions of architectural form. One of the most influential ideas derived from the frame structure is the modern curtain wall. [**1.1**]

Historian Carl Condit called the invention of skeleton-frame construction "the most radical transformation in the structural art since the development of the Gothic system of construction in the twelfth century."[2] The importance of this new technology extended beyond the physical frame; it allowed, perhaps even obligated, architects to reconsider the essential character of the exterior wall. Traditionally responsible for a wide range of aesthetic and technical tasks, the outer walls of a building were directly implicated by innovative structural methods. Whereas they formerly provided enclosure and structural support, the new frame presented an architectural dilemma. Freed of its load-bearing responsibilities, the exterior became a blank canvas. What should be the character of the new wall? What type of skin should enclose the skeleton structure? Although architects and engineers did not arrive at an immediate solution, the curtain wall eventually emerged as a widely accepted response. After more than a century of development, the frame structure and its corollary, the curtain wall, continue to dominate construction today.

From his perspective in the high-modern period of the 1950s, Rowe recognized the importance of Chicago's late-nineteenth-century building boom and the advancements made during that period. In fact, he equates the relationship between his contemporaries and the city of Chicago to that of the High Renaissance architects and Florence, Italy. The rebuilding effort in the years following the Great Chicago Fire of 1871, which devastated the central business district, was remarkable. Within twenty years, the downtown Loop area was rapidly redeveloped with taller and taller buildings for which the city's architects methodically explored radically original methods of construction. This intense effort was driven in part by a population explosion: at the time of its incorporation in 1837, the city had four thousand inhabitants; by 1850, there were thirty thousand; and by 1890, it surpassed one million.[3] The city was quickly becoming an epicenter of commerce and culture. As density and land values increased, the economic

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1.4
Second Studebaker Building, Chicago, Illinois, Solon Spencer Beman, 1896

1.5
Gage Group Buildings, Chicago, Illinois, Holabird and Roche, 1899

benefits of building taller were obvious. Financial demand converged with the commercial availability of elevators and advancements in structural framing, leading to the emergence of the skyscraper, which in turn had remarkable consequences for the building enclosure.[4]

The work of a group of architects active in the 1880s and '90s—who later became known as the Chicago School—defined this era of experimentation.[5] Notable buildings from this group are quite numerous and include William LeBaron Jenney's Leiter Building I (1879), in which timber girders and floor joists were supported by a grid of cast-iron columns, a common construction method at the time. [**1.2**] A unique strategy was used at the exterior, however, where instead of a bearing wall, iron columns located just inside the enclosure carried gravity loads at the floor perimeter. These columns were clad in non-load-bearing brick piers, kept consistently narrow to maximize the floor-to-ceiling windows. Also designed by Jenney was the ten-story Home Insurance Company Building (1885), considered by many to be the first modern skyscraper,[6] as well as the Ludington Building (1891), one of the first all-steel structures. [**1.3**] Later steel-framed buildings, such as the second Studebaker Building (1896) by Solon Spencer Beman and the Gage Group Buildings (1899) by Holabird and Roche in collaboration with Louis Sullivan, feature enclosures that express the underlying frame structure more directly. [**1.4**] Beman's Studebaker Building is dominated by large windows and iron-plate spandrels.

The three Gage Group Buildings were designed to maximize daylighting for the client's millinery workers. Sullivan was responsible for the design of the more elaborate facade of the northernmost building, which in its articulation suggests a multistory curtain hanging from the cornice. [**1.5**]

A comparative study of two late-nineteenth-century Chicago office buildings—the Monadnock Block (1891) and the Reliance Building (1895)—is useful in understanding the impact of the frame structure and the eventual emergence of the curtain wall. Among the many remarkable aspects of these two very different buildings is the fact that they were both designed by the office of Daniel H. Burnham and built within five years of one another. Considered together, the Monadnock Block and the Reliance Building illustrate an important shift in the concept of structure and skin.

A prolific architect and planner, Burnham was also responsible for overseeing the planning and construction of the 1893 World's Columbian Exposition, and his office produced influential city plans for Chicago, Washington, D.C., and San Francisco. Burnham always worked with a junior partner, and the common perception was that Burnham handled the business side of the firm while his partner directed the design process, with Burnham acting as consultant and critic.[7] His first partner, John Wellborn Root (of the firm Burnham and Root), was the primary designer of the Monadnock Block. Root began work on the Reliance Building, but following his untimely death in 1891, the firm was renamed D. H. Burnham

1.6
Monadnock Block, Chicago, Illinois, Burnham and Root, 1891

1.7
Monadnock Block; typical lower-, middle-, and upper-floor plans

1.8
Monadnock Block

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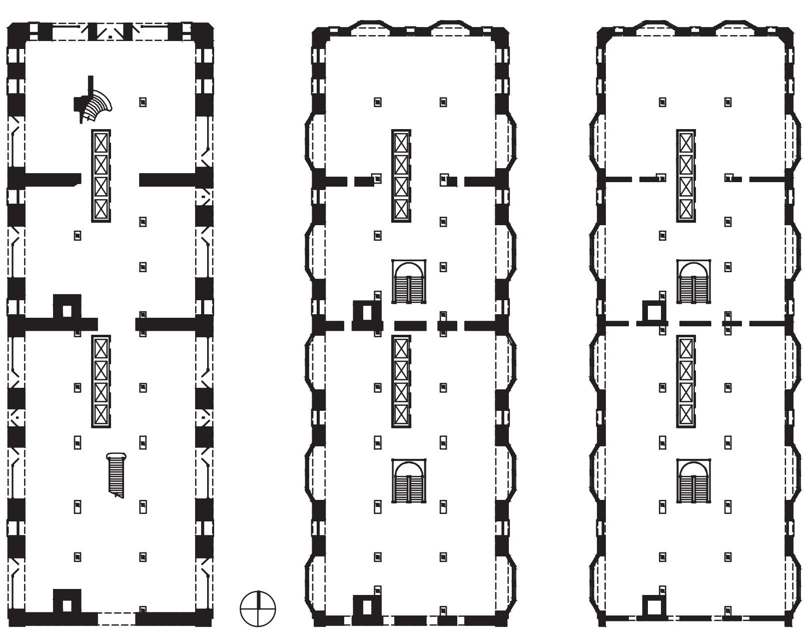

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and Company and a new design partner, Charles B. Atwood, took responsibility for the final design.

Burnham and Root's sixteen-story Monadnock Block was, for a brief period, the world's tallest office building. [1.6] Although in some ways unprecedented, particularly in height and in its lack of facade decoration, the building was archaic in terms of its structural technology. At a time when all-steel frame construction was considered the future of the tall building, the Monadnock Block was built using the traditional arrangement of solid load-bearing masonry walls at its exterior, with interior floor loads carried on cast-iron columns and wrought-iron beams. Although Root's initial scheme called for a steel frame with an ornately decorated facade of multicolored brick and terra-cotta, the architect was directed by his clients, Peter and Shepard Brooks, to abandon ornamental embellishments and revert to a traditional masonry wall structure.[8] Load-bearing masonry requires that the wall's thickness increase in relation to a building's height. The taller the structure, the thicker the wall required to carry its compressive loads to the ground, which in turn requires a heavier foundation to support the weight of the building. [1.7] This type of construction, as commonly used in Chicago, was considered to have a practical height limit of ten stories. The brick wall of the sixteen-story Monadnock Block is 72 inches (1.8 meters) thick at its base. The width of this massive wall, which reveals itself at its recessed windows, has an undeniably powerful presence that

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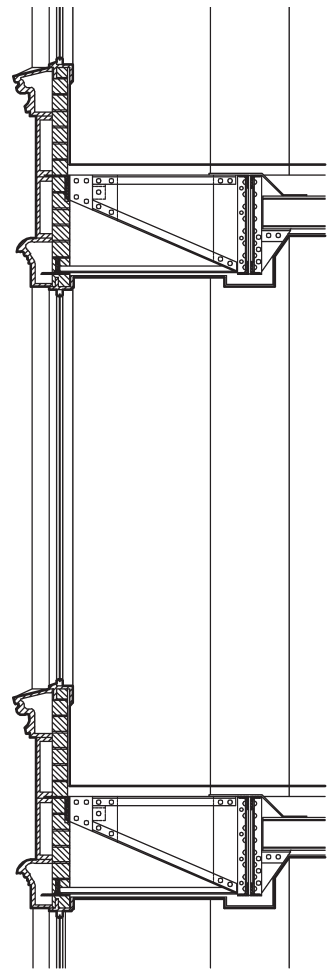
1.9
Reliance Building, Chicago, Illinois, D. H. Burnham and Company, 1895

evokes permanence and strength, but it also takes up valuable floor space, limits the size of the windows (and therefore the amount of natural light that reaches the interior), and was considerably less efficient than steel framing in terms of labor and time required for construction. [**1.8**] The weight of such a structure can also lead to problems of settlement. Although the Monadnock Block was designed to accommodate 8 inches (0.2 meters) of settlement, over the years it settled more than 20 inches (0.5 meters).[9] For these reasons, it was one of the last tall buildings to be built with solid masonry walls; however, architects did not immediately abandon the aesthetic of the brick wall. The transition to curtain wall construction was a gradual process, with an intervening period in which a great many frame-structure buildings were built that were, as William Dudley Hunt described, "masonry to the eye but steel or reinforced concrete to the mind."[10]

Built just four blocks away and four years later, the fifteen-story Reliance Building is a striking departure from the Monadnock Block and a radical reinterpretation of the office-building facade. [**1.9**] Although critics at the time were apparently not enthralled—"It is hardly to be supposed... that even the designer will consider it a masterpiece," Charles Jenkins wrote[11]—the building was eventually recognized as a milestone accomplishment of the Chicago School. Writing about the Reliance Building several decades later, Condit claimed, "If any work of structural art in the nineteenth century anticipated the future, it is this one," adding that "Atwood succeeded in developing almost to its ultimate refinement the modern dematerialized

1.10
Reliance Building, wall section, 1895

1.11
Reliance Building, typical floor plan



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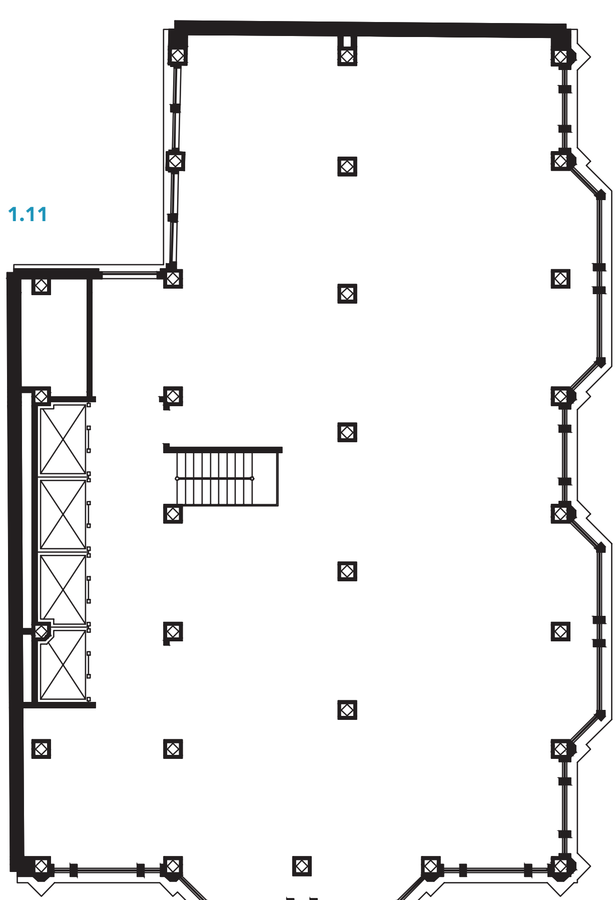

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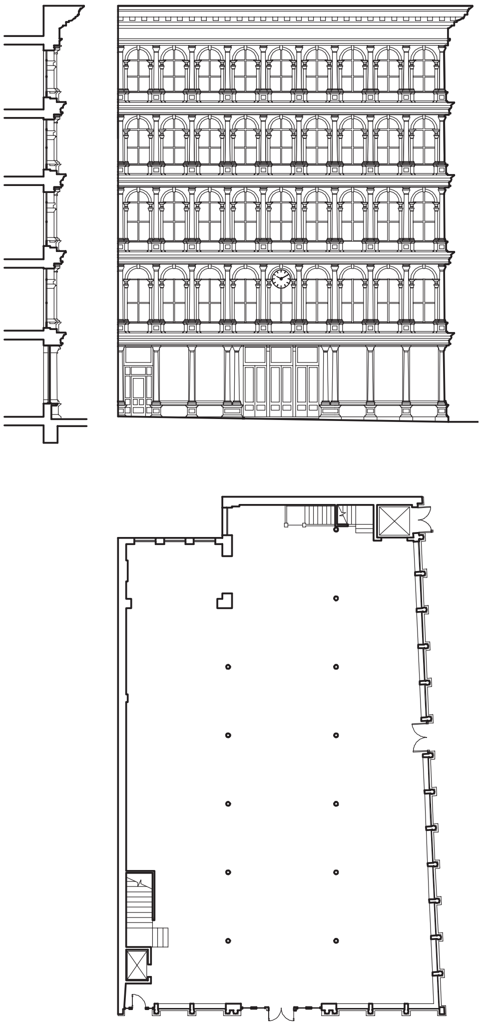
curtain wall."[12] The facade is characterized by great expanses of glass arranged in the "Chicago window" fashion, with a large central pane of glass flanked by narrow operable windows. The glass is set nearly flush within surrounding thin bands of glazed-white terra-cotta cladding delicately articulated with Gothic-inspired ornamentation. [**1.10**] The client, William E. Hale, was determined to have a thoroughly modern building, calling for abundant natural light, the latest elevator technology, full electric service, and a telephone in each office.[13]

It is perhaps difficult to grasp the impact that the Reliance Building must have had on Chicagoans in 1895. With their delicate white framing, the glass walls, alternately transparent or reflective depending on the time of day and perspective, would have stood in stark contrast to the neighboring dark brick buildings. The speed of construction must have been startling as well. Working with the engineer Edward C. Shankland, Atwood designed a riveted steel-frame structure, the top ten stories of which were erected in just two weeks, a pace unthinkable with traditional masonry structures. In plan, the steel columns are effectively masked from the exterior, incorporated into corners and projecting bay windows. [**1.11**] The effect is suggestive of the forthcoming modern curtain wall: a minimal, modular expression of the frame's grid with an infill of large glass panels. The wall is simultaneously informed and inflected by the structural frame, yet is free of it. In later work, such as the Flatiron Building (1902) in New York City, D. H. Burnham and Company would return primarily to the more conservative Beaux Arts–influenced style of the World's Columbian Exposition.[14] To modern architects, it would later seem that Burnham and Atwood had essentially turned their backs on the new dialogue between structure and skin that they initiated in the Reliance Building, leaving it to other architects to take up the discussion.

Both the Monadnock Block and the Reliance Building were designated Chicago Landmarks in the 1970s, and both are still in use today. The Monadnock Block continues to function as an office building, while the Reliance Building, following an extensive restoration in 1999, has been converted to a hotel. In a nod to its designers, the building



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is now known as Hotel Burnham; its ground-floor restaurant is the Atwood Cafe.

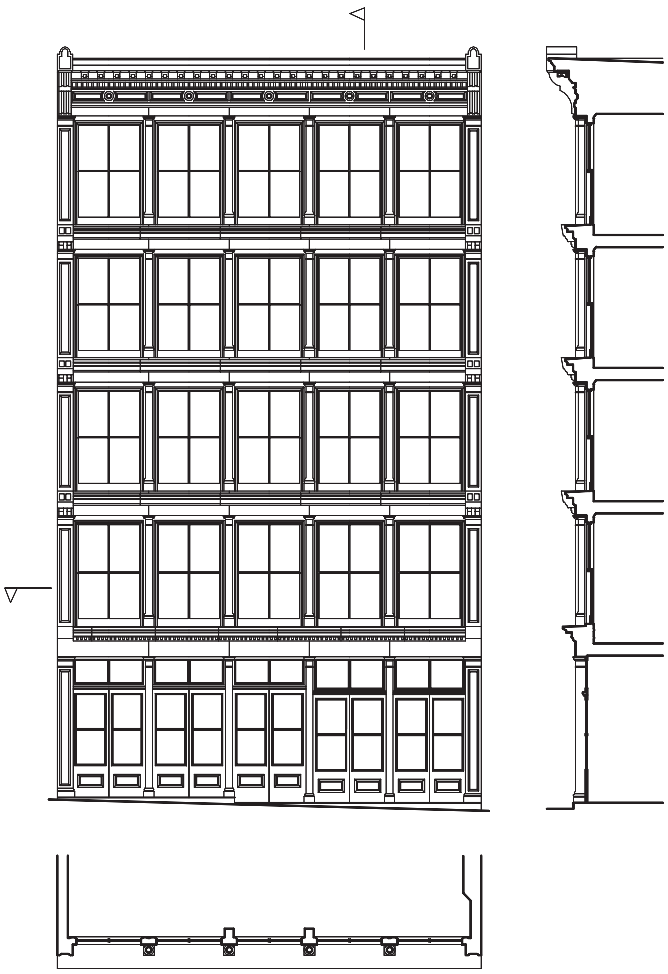
The frame structure had reached an important turning point in Chicago in the late nineteenth century, when the availability of steel (a stronger alternative to iron), among other factors, opened up new possibilities at an unparalleled scale. While the concept of the frame structure was certainly advanced during this period, it was not invented then. An exhaustive history of the evolution of frame structures is beyond the scope of this work, but it is worth a brief digression to note some important precedents to the Chicago frame. Kenneth Frampton has delineated the progression of iron applications over the course of the nineteenth century in Europe and the United States, tracing its use from railroads and bridges to the roofs of market halls and arcades and eventually to the framing of fully glazed conservatories and exhibition halls, such as Joseph Paxton's Crystal Palace (1851) in London.[15] With the rise of industry came new uses for iron. Frampton wrote:

The materials of the railway, cast and wrought iron, gradually became integrated into the general building vocabulary, where they constituted the only available fireproof elements for the multi-story warehouse space required by industrial production.[16]

Frampton also noted that the standard structural I-beam shape, ubiquitous in frame structures today, first emerged from the typical railway section. Notable early uses of iron framing include two ground-breaking English mill buildings: the first in 1792, by William Strutt, in Derby; and the second in 1796, by Charles Woolley Bage, in Shrewsbury. Each employed cast-iron columns carrying segmental brick arches. These were followed by the engineer Thomas Telford's 1829 warehouses at St Katherine Docks, in London, which were built with iron framing encased in brick, refining the techniques used in earlier buildings, with incremental improvements over previous installations.

1.12
Haughwout Building, New York, New York, partial section, west elevation, and floor plan. John P. Gaynor, 1857

1.13
Haughwout Building, south elevation



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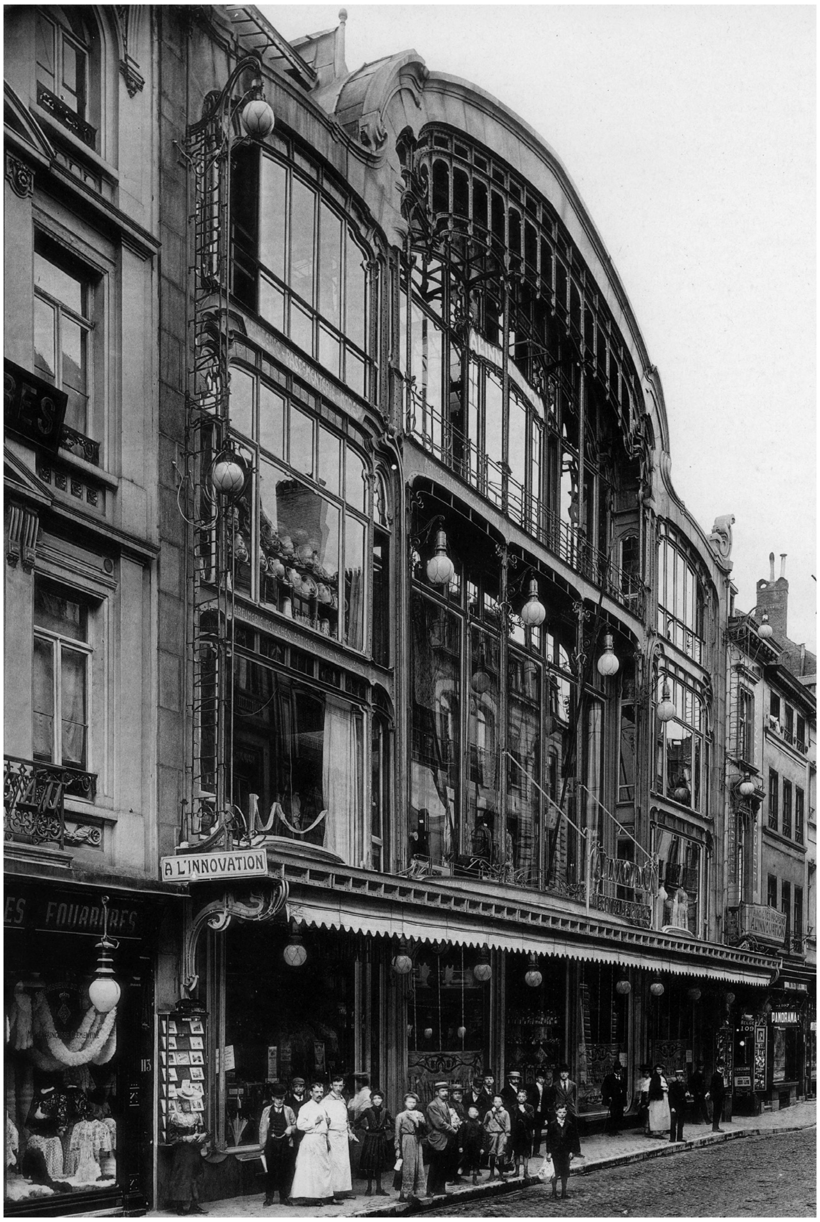
1.14
Thomas Gantt Building, St. Louis, Missouri, partial section and partial floor plan; architect unknown, 1877

1.15
Thomas Gantt Building

Of particular interest in the study of the modern curtain wall is the mid-nineteenth-century era of cast-iron architecture, typified by the work of New York designer/builder James Bogardus, the pioneer of the multistory self-supporting cast-iron facade.[17] Bogardus received a patent in 1850 for his construction system of manufactured cast-iron columns and girders bolted together to form a rigid frame, which he employed in commercial projects such as the four-story Laing Stores (1849) and a five-story building at 254–260 Canal Street (1857), which is one Bogardus's few surviving buildings. He vigorously marketed the cast-iron facade as an efficient and adaptable system that was quick to erect, relatively inexpensive, and resistant to fire. The Haughwout Building (1857) on Broadway in New York City was designed by the architect John P. Gaynor to resemble a Venetian palazzo, and it illustrates the tendency, which was common at the time, to retain intricate historicist ornament even while deploying a new method of construction. [**1.12 + 1.13**] Still occupied today, the building was the first structure to be served by a passenger elevator, installed by Elisha Graves Otis. Another striking cast-iron building, which Sigfried Giedion called one of the finest of this period and a forerunner of the Chicago skyscrapers,[18] was the Thomas Gantt Building (1877) in St. Louis, Missouri (dismantled in the 1940s). [**1.14 + 1.15**] These cast-iron facades, with their clear articulation of large metal-framed windows and their system of modular units prefabricated and bolted together on site, clearly prefigure the modern curtain wall.

At the turn of the twentieth century, architects continued to explore the frame structure and its dual implications for interior space and exterior expression. In 1897, Frank Lloyd Wright designed the provocative Luxfer Prism Skyscraper, an unbuilt plan for a ten-story steel-framed building with a gridded facade of slightly projecting floor-to-ceiling glass panels.[19] In Belgium, the architect Victor Horta worked with iron and steel, developing a vocabulary expressive of the ductile nature of those materials. In his buildings, such as the Maison du Peuple (1899) and L'Innovation Department Store (1903), the grid is clearly expressed on the facade with thin iron elements framing large



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panes of glass, but the frame is also shown to be adaptable, embellished now with the subtle curvatures of the Art Nouveau aesthetic.[20] [1.16] It was also around this time that architects began designing frame structures with reinforced concrete on a significant scale. In Paris, Auguste Perret's eight-story Rue Franklin Apartments (1903) used a system of reinforced-concrete construction that had been pioneered and patented by the builder François Hennebique in the 1890s. [1.17] The building was one of the first concrete buildings to use the structural frame itself (clad in terra-cotta) as the primary exterior expression, infilled almost entirely with glass.

Architects eventually began to question the standard coplanar positioning of structure and skin. When the structural frame first arrived to replace the solid bearing wall, it generally retained the wall's position at the outermost surface of the building. With this erosion of the bearing wall, the frame made it possible to open up the facade, allowing for the placement of larger and larger windows between structural members, with the obvious benefits of increased daylight, views, and opportunities for ventilation. The window remained a discrete unit, however big it became, serving as a transparent counterpoint to the opaque grid of structure that framed it. In the first two decades of the twentieth century, architects began experimenting with the possibility of separating the glass membrane of the window from the structural frame, transposing the glass from individual window to continuous wall. Walter Gropius described this phenomenon, writing that "as a direct result of the growing preponderance of voids over solids, glass is assuming an ever greater structural importance," with the

1.16
L'Innovation Department Store, Paris, France, Victor Horta, 1903

1.17
Rue Franklin Apartments, Paris, France, Auguste Perret, 1903

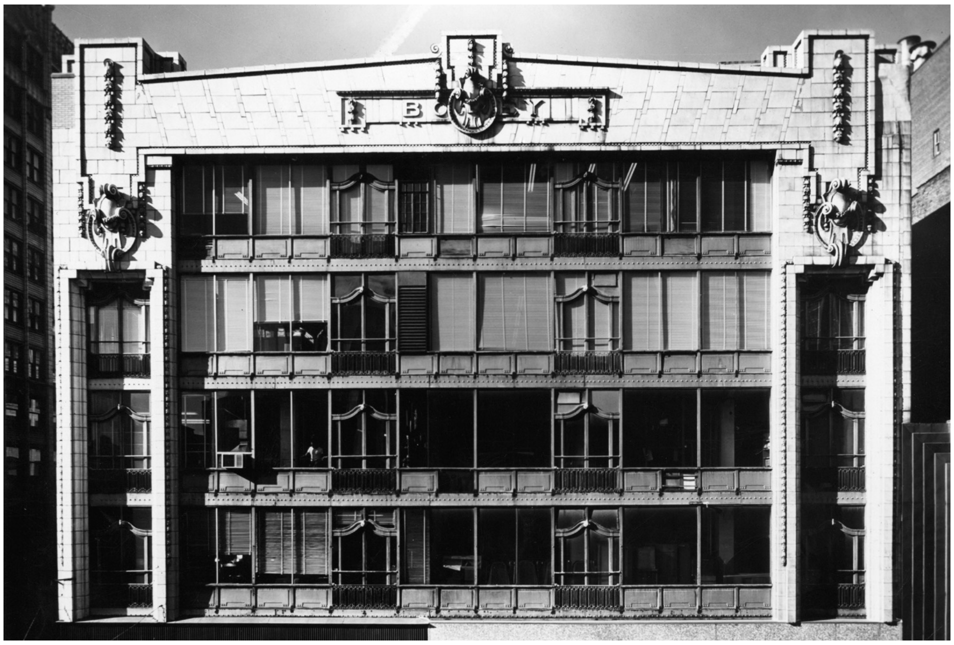
1.18
Fagus Shoe-Last Factory, Alfeld an der Leine, Germany, Walter Gropius and Adolf Meyer, 1911

1.18

walls becoming "mere screens stretched between the upright columns of this framework to keep out rain, cold, and noise."[21] The gradual improvement in steel and concrete technologies, Gropius wrote, "naturally leads to a progressively bolder (i.e. wider) opening up of the wall surfaces, which allow rooms to be much better lit."[22]

These concepts are evident in several industrial buildings constructed in Germany just after the turn of the century, perhaps most clearly at the Fagus Shoe-Last Factory (1911), designed by Gropius and Adolf Meyer in Alfeld an der Leine. [**1.18**] Exposed brick-faced concrete columns are recessed behind the plane of glass, revealing the wall to be a nonstructural "curtain." Between each column, the curtain wall is articulated as a continuous, three-story-high vertical band passing uninterrupted beyond the edge of each floor slab. The wall, with its organizing grid of slender steel mullions, is divided into clear glass panels and metal spandrels, the latter corresponding to the location of floor slabs. At the corner, the structural column is eliminated altogether, allowing the glass planes to meet at a single corner mullion that is no larger than typical. By comparison, the Fagus Shoe-Last Factory makes the curtain wall at the AEG Turbine Factory in Berlin, built just two years earlier to the design of Peter Behrens (for whom Gropius had worked), seem old-fashioned and inelegant. In the Fagus building, we find many of the elements that would eventually constitute the vernacular language of the curtain wall: metal mullions spanning vertically from floor to floor, subdivided into a grid of glass panels, the dimensions of which were determined by available plate-glass sizes, and the integration of opaque spandrel panels where needed to mask the underlying structure. A strategy similar to Gropius's had been used in the fascinating Margarete Steiff toy factory (1903) in Giengen. Although unconfirmed, it is believed that Richard Steiff, the grandson of the company's founder, produced the design.[23] In this instance, the structural steel frame is encased in a double-layer facade, with a continuous outer skin of glass panels set in iron mullions suspended in front of the structure and extending from ground to roof and from corner to corner, with a second wall of glass on the inner side of the columns. Apparently designed for purely utilitarian purposes—admitting ample daylight to the factory while mitigating the inherent thermal issues of single-pane glass—it stands as one of the earliest continuous glass curtain walls and a remarkable precursor to the modern double-skin facades that would proliferate nearly a century later.

In the United States, two early-twentieth-century commercial buildings were particularly innovative in applying the curtain wall concept at an unprecedented scale. In these buildings, the structural frame is set back entirely behind the plane of a glass-and-metal facade, which is suspended from the structure in a continuous surface. The earlier and more obscure of the two is the Boley Building (1908) in Kansas City, Missouri, designed



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by Louis Curtiss. The later and better known is the Hallidie Building (1918) in San Francisco, California, by Willis Polk. Each of these buildings has at various times been identified as the first large-scale installation of the pure curtain wall concept. Each was built in the center of its respective city, and, like the Monadnock Block and Reliance Building, they mark an important shift in the development of the modern building envelope.

Curtiss's six-story steel-framed Boley Building is believed to be the first frame structure to use columns of solid rolled wide-flange sections rather than built-up members.[24] [1.19] The separation of skin and structure is emphatic; a continuous wall of glass and steel is suspended from cantilevered floor slabs, which extend five feet (1.5 meters) beyond the columns. The curtain wall, primarily large sheets of plate glass set within steel mullions, includes painted steel-plate spandrels and is framed by a cornice and corner bays clad in white-enameled terra-cotta (similar to the cladding of the Reliance Building). Curtiss, who practiced in Kansas City from the early 1890s until his death in 1924, was an eccentric character who regularly communicated with the spirit world and was a fervent believer in the Ouija board.[25] He was also an undeniably visionary designer. Though not particularly well received or understood at the time, the Boley Building was, in its structure and cladding, a clear precursor to the modern architecture of later decades.

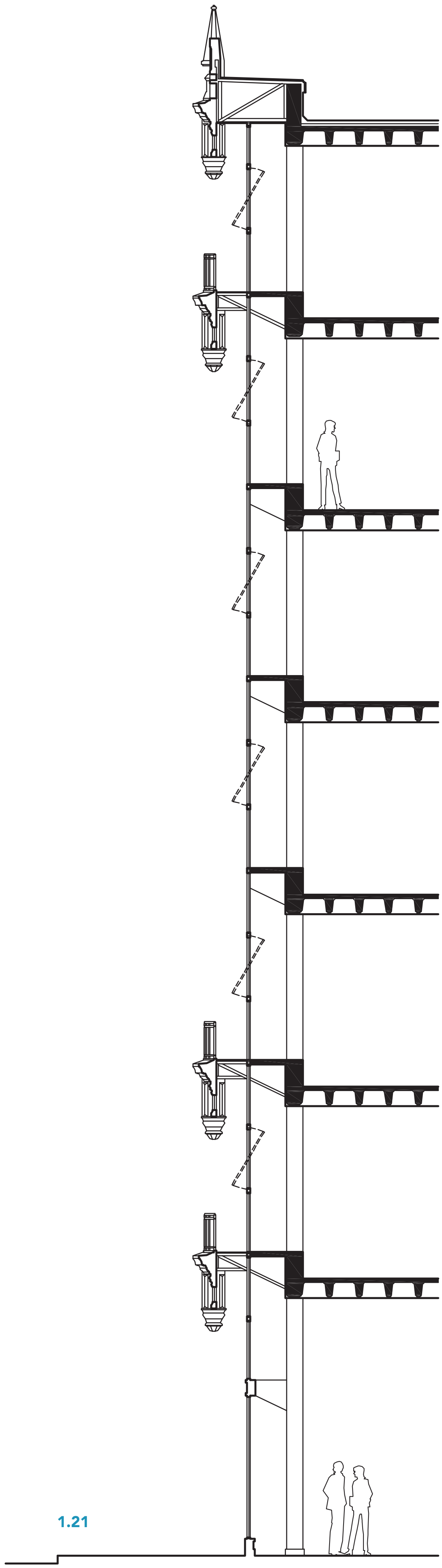
Ten years after its completion, at a time when most building facades were significantly less than 50 percent window, Polk's revolutionary Hallidie Building became the first large-scale urban building to feature an all-glass curtain wall.[26] [1.20] An unbroken seven-story wall of clear glass panels (with no opaque spandrels) is suspended 3 feet (0.9 meters) in front of the column line. The glass is fixed within a grid of narrow steel mullions, with the occasional pivoting sash for ventilation. The structural system is a reinforced-concrete frame. At the edge of each floor slab, an upturned perimeter beam supports a thin cantilevered slab, which in turn supports the curtain wall and acts as a firebreak between floors. [1.21] The stark purity of the gridded curtain wall is mediated by several ornate ironwork cornices and fire escapes that float in front of the glass wall. Polk's client was the University of California (the building is named for Andrew Hallidie, a former regent of the university and the inventor of the cable car), and the unusual decision to use an all-glass facade was allegedly a response to a tight budget and an accelerated six-month construction schedule.[27] A review of the building published in 1918 in *Architectural Record* pointedly avoids any discussion of aesthetics, focusing instead on the practical benefits of increased daylight and floor space, as compared to traditional masonry walls with recessed windows. The Hallidie Building, this article understates, "possesses more than ordinary interest to architects."[28] It also uncannily anticipates future developments in modern curtain wall design.

Interestingly, there is no indication in Polk's earlier work of anything similar to the groundbreaking Hallidie Building, which

1.19
Boley Building, Kansas City, Missouri, Louis Curtiss, 1908

1.20
Hallidie Building, San Francisco, California, Willis Polk, 1918

1.21
Hallidie Building, wall section



Frampton considers the "unique triumph of Polk's career."[29] As early as 1892, the architect had articulated an appreciation for innovation and a progressive stance regarding historic precedent, writing, "Standards in art are set by the best work of [the] ages, but no age…is compelled to take its beauty from preceding epochs.…We must neither depreciate nor imitate, but we should understand and originate."[30] There are also interesting connections between Polk and two other figures discussed above: Burnham and Curtiss. Before moving to San Francisco, Polk worked for a time in Kansas City, where he and Curtiss were both members of the Kansas City Architectural Sketch Club in the late 1880s and thus may have known each other personally.[31] The first commission of Curtiss's career had been the design of the Missouri State Building for the 1893 World's Columbian Exposition. And Polk was also associated with the firm of D. H. Burnham and Company for nearly a decade, which included a stint working in the Chicago office from 1902 to 1904,[32] where he surely would have become familiar with the Reliance Building, the Studebaker Building, and other works of the Chicago School. Although there is no conclusive proof, it is interesting to speculate that such connections may have influenced Polk's design of the Hallidie Building. Along with the Boley Building, it was listed in the National Register of Historic Places in 1971; both are still in use today, dwarfed by surrounding skyscrapers that are built on the principles they pioneered.

At the Bauhaus Building (1926), which Reyner Banham called "the first really big masterpiece of the modern movement,"[33] the glass curtain wall is given its first truly modern articulation on a large scale. Designed by Gropius and Meyer, the Bauhaus complex is sited in Dessau, Germany, and includes a five-story student dormitory wing, a three-story classroom wing, and a three-story workshop block. The facade of each wing gives an indication of the function within: the dormitory has individual punched windows and balconies, the classrooms are marked by larger groupings of strip windows, and the collective loft spaces of the workshop are enclosed by a continuous glass curtain wall that is hung outside of the reinforced-concrete frame structure and spans the full height of

1.22

1.22
Bauhaus Building, Dessau, Germany, Walter Gropius and Adolf Meyer, 1926

the building. Perhaps the most striking element of all is the curtain wall itself, which is technically similar to that of the Hallidie Building but utterly free of any historicist ornament. [**1.22**] It clearly builds upon the architects' earlier design for the Fagus Shoe-Last Factory while making certain refinements, including the elimination of opaque spandrels and the complete setback of the structure. With its steel mullions, pulley-operated vents, and repetition of standardized units, the Bauhaus Building curtain wall epitomizes Gropius's concept of a *new architecture*, characterized by rationalization, machine production, and a new spatial vision.[34] Certainly not without controversy or technical deficiencies (such as condensation on the single-pane glass and insufficient acoustic insulation), the curtain wall looms large as an icon of the modern movement and as an "emblem of the machine age."[35] In 1945, an air raid on Dessau destroyed the curtain wall of the workshop building. Though rebuilt to some degree, it remained in various states of disrepair until it was restored to the original design in 1976. In 1996, the entire Bauhaus complex was added to the UNESCO World Heritage List; today it houses the Bauhaus Dessau Foundation, a center for interdisciplinary design research.

If the frame structure can be considered a feat of engineering, then the curtain wall was architecture's response, exploiting the frame's potential to reconceive the building envelope, thereby transforming not only the face of the modern building but also the experience of space within. The early, incremental development of the curtain wall was infused with a spirit of experimentation and informed by a diverse set of ideas about new construction methodologies, new materials, efficiency, mass production, and, as we will see in the next chapter, the expressive possibilities of glass.

Endnotes

1 Colin Rowe, “Chicago Frame,” first published in *Architectural Review*, November 1956, 285–89. Reprinted in Colin Rowe, *The Mathematics of the Ideal Villa and Other Essays* (Cambridge, Mass.: MIT Press, 1976), 285–289.
2 Carl W. Condit, *The Chicago School of Architecture: A History of Commercial and Public Building in the Chicago Area, 1875–1925* (Chicago: University of Chicago Press, 1964), 79.
3 Louis H. Sullivan, *The Autobiography of an Idea* (New York: Dover Publications, 1956), 308; and Kenneth Frampton, *Modern Architecture: A Critical History* (London: Thames & Hudson, 1992), 21.
4 The first hydraulic elevator in Chicago was installed in 1870 at the Burley and Company Building on West Lake Street. See Condit, *The Chicago School of Architecture*, 21. In 1899, the critic Montgomery Schuyler claimed that “the elevator doubled the height of the office building and the steel frame doubled it again,” as quoted in Frampton, *Modern Architecture*, 52.
5 Although originally coined by the architect Thomas Tallmadge in 1908 to signify a group of residential designers that included Frank Lloyd Wright, the term *Chicago School* has since been expanded to include the commercial architects of the 1880s and 1890s.
6 Sigfried Giedion, *Space, Time and Architecture: The Growth of a New Tradition* (Cambridge, Mass.: Harvard University Press, 1967), 208.
7 A. N. Rebori, “The Work of Burnham and Root,” *Architectural Record*, July 1915, 41.
8 Kristen Schaffer, *Daniel H. Burnham: Visionary Architect and Planner*, ed. Scott J. Tilden (New York: Rizzoli, 2003), 10.
9 Condit, *The Chicago School of Architecture*, 67.
10 William Dudley Hunt, *The Contemporary Curtain Wall* (New York: F. W. Dodge Corp., 1958), v.
11 Charles E. Jenkins, “A White Enameled Building,” *Architectural Record*, January–March 1895, 299.
12 Condit, *The Chicago School of Architecture*, 111. Similarly, Giedion calls the Reliance Building “an architectonic anticipation of the future” and suggests that it was an inspiration for Mies van der Rohe’s visionary skyscraper projects of the 1920s. See Giedion, *Space, Time and Architecture*, 388. The so-called dematerialization of the curtain wall is the subject of interesting debate in Joanna Merwood, “The Mechanization of Cladding: The Reliance Building and Narratives of Modern Architecture,” *Grey Room* (Summer 2001): 52–69.
13 Jay Pridmore, *The Reliance Building: A Building Book from the Chicago Architecture Foundation* (San Francisco: Pomegranate, 2003), 6.
14 Rowe calls the World’s Columbian Exposition the “debacle which overwhelmed these Chicago architects” and “cut short their development.” See Rowe, “Chicago Frame,” 286. Interestingly, when this essay was reprinted in *The Mathematics of the Ideal Villa and Other Essays*, Rowe inserted a qualifier that was not present in the original version: the exposition was now an “alleged debacle.”
15 The Crystal Palace, a grand exhibition hall, was essentially an immense iron-framed shed clad on all sides in glass. It is often held to be an influence on later curtain wall development, although this is disputed by David Yeomans in “The Origins of the Modern Curtain Wall,” *APT Bulletin*, 32, no. 1 (2000): 13.
16 Frampton, *Modern Architecture*, 32. Frampton also quotes Walter Benjamin’s 1930 statement, “The rail was the first unit of construction, the forerunner of the girder.”
17 Margot Gayle and Carol Gayle, *Cast-Iron Architecture in America: The Significance of James Bogardus* (New York: W. W. Norton, 1998). In the foreword, Philip Johnson cites Bogardus as an influence on the work of Mies van der Rohe at the Illinois Institute of Technology.
18 Giedion, *Space, Time and Architecture,* 202.
19 Wright would eventually become more interested in working with the cantilever than the frame. For a discussion of the Luxfer Prism project’s role in Wright’s oeuvre, see Michael Mostoller, “The Towers of Frank Lloyd Wright,” *Journal of Architectural Education*, 38, no. 2 (Winter 1985): 13–17.
20 The historian William J. R. Curtis calls the facade of the Maison du Peuple “every bit as ‘radical’ as Sullivan’s contemporary skyscraper designs in Chicago,” in *Modern Architecture Since 1900* (London: Phaidon Press, 2005), 56. First published in 1982.
21 Walter Gropius, *The New Architecture and the Bauhuas* (Cambridge, Mass.: MIT Press, 1965), 26–9.
22 Ibid., 26.
23 Christian Schittich, et al., *Glass Construction Manual* (Basel: Birkhäuser, 1999), 25.
24 Fred T. Comee, “Louis Curtiss of Kansas City,” *Progressive Architecture*, August 1963, 128–34.
25 Ibid.
26 Keith W. Dills, “The Hallidie Building,” *Journal of the Society of Architectural Historians*, 30, no. 4 (December 1971): 323–29.
27 Nory Miller, “Down and Dirty in 1917,” *Progressive Architecture*, November 1981, 108–9. The original color scheme of the building was blue and gold, the colors of the University of California.
28 MacDonald W. Scott, “A Glass-Front Building,” *Architectural Record*, October 1918, 381.
29 Kenneth Frampton and Yukio Futugawa, *Modern Architecture: 1851–1945* (New York: Rizzoli, 1983), 194.
30 Willis Polk, “A Matter of Taste,” *Wave*, November 12, 1892, 16. As quoted in Richard W. Longstreth, *On the Edge of the World: Four Architects in San Francisco at the Turn of the Century* (New York: Architectural History Foundation and Cambridge, Mass.: MIT Press, 1983), 93.
31 Donald L. Hoffmann, “Pioneer Caisson Building Foundations: 1890,” *Journal of the Society of Architectural Historians*, 25, no. 1 (March 1966): 68–71.
32 Longstreth, *On the Edge of the World*, 299–301.
33 Reyner Banham, *Age of the Masters: A Personal View of Modern Architecture* (New York: Harper & Row, 1962), 157.
34 Gropius, *The New Architecture and the Bauhaus*, 19–24.
35 Curtis, *Modern Architecture Since 1900*, 196.