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A MACHINE FOR LIGHT: THE BUILDING AS LUMINAIRE

Architecture can transform daylight and electric light into much more than just a 'building system.' Here are some examples from across the centuries

By Clifton Stanley Lemon

Light is a key driver of architectural form. Geometries that amplify, reflect and modulate light occur at many different scales in both buildings and luminaires, and in many surprising and fascinating ways in nature. The history of architecture and building in the pre-electric lighting period yields many rich examples of the interplay of light and building. The advent of electric lighting gave rise to an entirely different understanding of this interplay, sometimes obliterating centuries-old building practices and creating and enabling entirely new ones. Lighting is also a key part of sustainable design, which is predicated on first using onsite resources—daylight being one of the most important. And lighting the human beings that live and work in buildings is as important as lighting the spaces themselves, something we all too often forget.

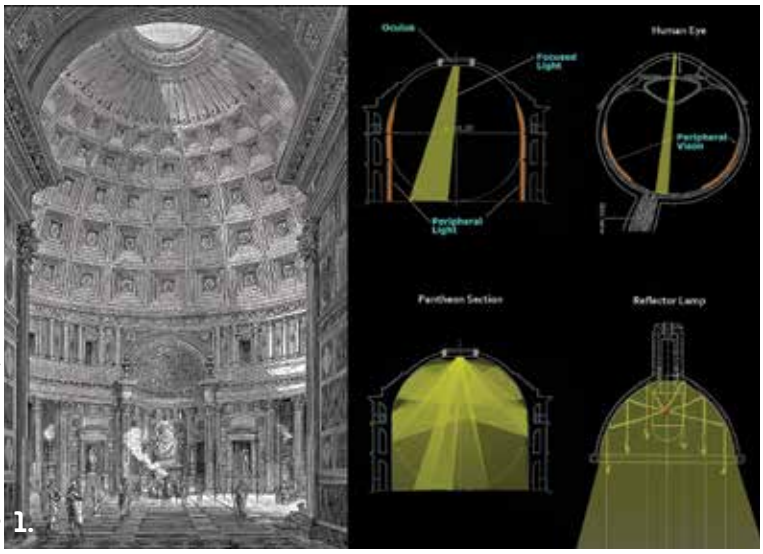
All of which leads us to ask: *What would a building look like if its primary purpose, beyond shelter, was to provide optimal light?* The usual design sequence followed today—building envelope first, lighting added later on (often as an afterthought)—is neither optimal nor consistent with historical practice. Turning this sequence around, starting with light is not as crazy as it sounds. We've been doing it ever since we've been making buildings—we've just mostly forgotten about it in the last century or so.

For the last few years, my colleague Jeremy J. Steinmeier and I have been teaching a course we call *A Machine for Light*, which we recently did as a webinar for IES. The title is a play on the modernist dictum of the architect Le Corbusier "A house is a machine for living in"; if a building can be a machine for living it can certainly be a "machine for light."

A "luminaire building" is one that provides optimal light—well balanced, adjustable, comfortable and beautiful—like a good luminaire. Thinking of a building as a luminaire, and vice versa, means understanding that geometries that are good for managing light at small scales also work at large ones, and that architectural forms that manage daylight well also can manage electric light well. A luminaire building has the proper interplay of daylight and electric light, and well balanced ambient, task, accent and decorative lighting.

The building that inspired us to think about buildings as luminaires was the **Pantheon (1)** in Rome, originally built by Marcus Agrippa in 27 BC and still the world's largest unreinforced concrete dome. Its geometry mimics that of the human eye: focused light ends up where it's most useful, and diffused light is delivered on vertical surfaces, where we perceive it with our peripheral vision. The ceiling opening, appropriately called the oculus (Latin for eye), delivers daylight while the building's shape distributes it beautifully and evenly.

The Pantheon's geometry also bears similarities to the shape of many luminaires like parabolic reflectors, a key innovation in lighting that greatly improved fixture efficiency and directional control.



Images: iStock/Clifton Stanley Lemon

The Pantheon's geometry mimics the human eye and reflector lamps.

Photo: Creative Commons

Philip Johnson's Glass House, 1948-49, lit by Richard Kelly.

Arcs in particular—parabolic, circular, catenary and cycloid—can direct light beautifully and efficiently in both buildings and luminaires, but other geometries can as well, when applied correctly. This principle is central to the exploration of the relationship between light and architecture.

Philip Johnson's Glass House (2) is essentially a 2,000-sq ft luminaire building. Lighting designer Richard Kelly, collaborating closely with Johnson, solved the "black mirror" problem: in an interior space with large windows at night, a resident knows she can be seen from outside but can't see out because of reflections. Kelly's elegant solution was to light the exterior of the house, making it part of the interior.

How did we build before electric light? In search of examples of buildings designed with optimal light as a primary objective, we found beautiful luminaire buildings across many historical periods.

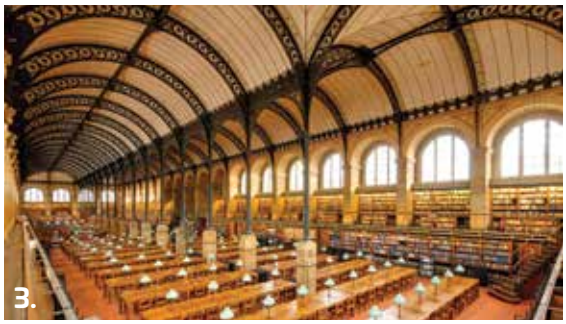


Photo: Wikimedia Commons

The reading room of the Bibliothèque Sainte-Geneviève in Paris by Henri Labrouste, 1850.

Image: iStock

Adequate light for machinery and workers necessitated larger building volumes during the Industrial Revolution.

The 1977 book *A Pattern Language*, by California architects Christopher Alexander, Sarah Ishikawa and Murray Silverstein, describes design patterns found in architecture all over the world, throughout history. It details methods for constructing practical, safe and attractive designs at every scale: cities, neighborhoods, gardens, buildings, rooms, built-in furniture and fixtures down to the level of doorknobs. Many of the patterns of building in the book directly incorporate light; we use these to identify various qualities of luminaire buildings.

Libraries and monasteries (3)—purpose-built for information work—are some of the most beautiful early examples of pre-electric luminaire buildings. Arched ceilings and ample clerestory windows provided wonderful ambient light, while small, efficient reading lamps provided excellent, low-glare task lighting. This is still a perfect formula for today's office environment.

During the **Industrial Revolution (4)**, the need to house machinery and large numbers of workers while providing adequate light necessitated larger building volumes. Before gas and electric lighting, daylight was the only available light sufficient for the detailed and often dangerous tasks performed in these environments. Tall ceilings and clerestory windows allowed light to penetrate into the core of the building while mitigating glare.

Photo: iStock

The Flatiron Building in New York by Daniel Burnham, 1902.

Photo: Courtesy of Omar Hason

The library of the Benedictine Abbey in Mt. Angel, Oregon by Alvar Aalto, 1972.

The thin floorplates of the **Flatiron Building (5)**, driven by both high real estate prices and a sound pattern language approach, allow daylight deep into each space. A good window-to-wall ratio keeps insulation values high, and generous operable windows deliver excellent daylight and ventilation. Simple ideas like these from the past can be used today without buying into any particular design aesthetic.

There are many examples of excellent luminaire buildings in the 20th century modernist tradition and other styles—here I show two that demonstrate particularly compelling harmonies between light and building. The library of the **Benedictine Abbey (6)** in Mount Angel, OR by architect Alvar Aalto in the early 1960s features large clerestory windows and a skylights that let in a soft, pleasing light which permeates the library. Aalto uses the techniques of Modernist architecture and the International Style, but with an organic, personal touch. The iconic **Kimbell Art Museum (7)** in Fort Worth, TX, illuminates its galleries with indirect natural light while excluding direct sunlight which would damage the artwork. Lighting designer Richard Kelly designed a reflecting screen made of perforated anodized aluminum with a specific curve that distributes natural light evenly across the ceiling's cycloid curve. This was one of the first architectural elements ever to be designed with computer technology.

Nature also inspires this fusion of architecture and light. Biomimetic design is an approach to the design of man-made devices, processes, systems or buildings, based on imitating forms found in nature. It's seen in many different forms and locations throughout history and recently is being combined with generative design, advanced modeling and intelligent building technology to deliver structures never before possible, at a wide range of scales. These can interact with light in surprising ways. Biomimetic designs can be more resilient, adaptable and regenerative.

An early 20th century example is Frank Lloyd Wright's iconic **Johnson Wax Building (8)**, inspired by lily pads on a pond. A series of thin white dendriform columns rise to spread out at the top, forming the ceiling. The spaces between the circles are set with skylights, creating a clerestory effect and letting in a pleasant soft light.

The **Biomimetic Office (9)** by UK architect Michael Pawlyn represents a new paradigm as the first office building that has ever been comprehensively designed with biomimicry. A main design requirement was that all the general lighting in the building would be daylight. The design team found inspiration from an amazing variety of sources: spookfish, stone plants and brittlestars for daylighting solutions; bird skulls, cuttlebone, sea urchins and giant amazon water lilies for the structure; ter-

Photo: Wikimedia Commons

Kimbell Art Museum, by Louis Kahn, lit by Richard Kelly, 1972.

Photo: Wikimedia Commons

Johnson Wax Building by Frank Lloyd Wright, 1950.

mites, penguin feathers and polar bear fur for the environmental control; and mimosa leaves, beetle wings and hornbeam leaves for solar shading. When completed, this project will be one of the lowest energy office buildings in the world.

Finally, how can we build sustainably with light? In recent decades architects and engineers have codified a set of best practices for sustainable building. Many are not new at all but come from a rediscovery of fundamental principles that evolved over millenia. Over the last 150 years or so, advanced technology and construction techniques—including elevators, electric power, sophisticated plumbing, high performing glazing, air conditioning, steel framing, curtain walls, CAD, generative design, advanced controls and even artificial intelligence—have revolutionized architecture yet also had the unintended effect of causing many common sense building practices to be forgotten. What we call "daylighting" today is one

Image: Michael Pawlyn, Exploration Architecture

Biomimetic Office Building, by Michael Pawlyn, 2016.

of the most important of these. It's been unfortunately marginalized into a separate discipline, but this needs to change: architects and lighting designers need to transcend the boundaries of their disciplines in order to rediscover the past and integrate it into the future.

One of the goals of efficient, resilient and regenerative building design is the net-zero building, one that consumes no more energy than it produces. Net-positive buildings, which produce more energy, water and other "ecosystem services" than they consume, are now becoming possible. Efficient, beautiful lighting is crucial to achieving both.

Lighting designers don't think about sustainable design principles as much as architects and engineers because they're usually not involved in design decisions about the building envelope. But one of the key "services" a building provides is proper light, and these principles all apply to lighting design.

I would add one more sustainable design principle: Light the human being. The extensive and detailed lighting calculations we do today are not necessarily unique to our modern era. Leonardo da Vinci, one of the most influential artists of the Renaissance—the birth of humanism—understood what it meant to light people and architectural spaces, it was one of his primary concerns. Leonardo carefully observed, planned and calculated the effects of lighting on the subjects of his paintings. ◎

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