
PA

The Control of the Luminous Environment

Architecture, which for millenniums was dependent on natural sources of light, has in the past century increasingly turned to artificial sources. In the long run it must perfect the integrated use of both

by James Marston Fitch

We live in a luminous environment that is radically new for mankind. Until the 19th century life for most people was geared to the daily period of natural light between sunup and sundown. In George Washington's day 95 percent of Americans were farmers; daylight sufficed for their work, and they went to bed early not only because their hard labor made them sleepy but also because artificial lighting was primitive and expensive, illiteracy was general, books were few and the darkness of night still held much of its primordial menace. A symbolic illustration of the poverty of the luminous environment in the agricultural era is the picture of Abraham Lincoln heroically studying by the flickering light of an open fire.

The industrial revolution changed all of that. It created both the necessity and the means for a new order of artificial illumination. Machines could, and for efficient use should, be run around the clock. It became necessary not only to light up the nighttime but also to provide controlled illumination for the close and precise vision to which man now had to adapt himself—for operating machines and instruments, for reading and for the universal education that became an economic as well as a social and political necessity.

Today the majority of us work and spend most of our time in buildings, where the proper handling of daylight and the provision of artificial lighting are a *sine qua non*. In response to such needs artificial lighting, for both indoor and outdoor purposes, has been developed into a large and imaginative industry. Yet it cannot be said that many of the lighting systems are particularly well suited to the requirements of the job or to the health and comfort of the human eye. For one thing, they are often designed for appearance or for economy rather than for the utilitarian functions they are supposed to serve. For another thing, all too little study has been given to the psychology and physiology of vision in relation to illumination.

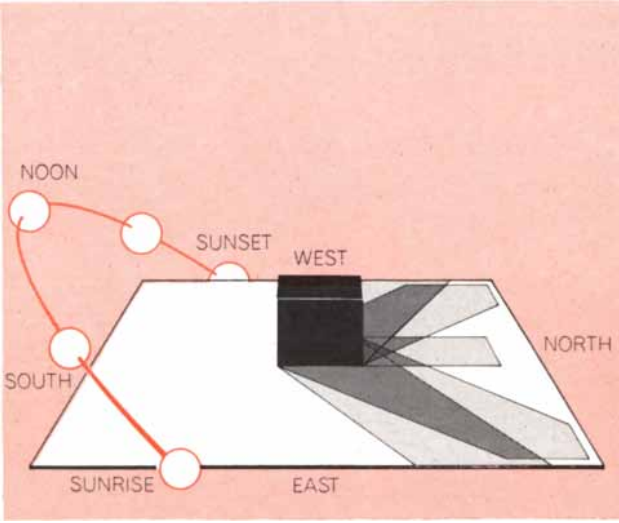
Within the visible portion of the spectrum the human eye is most sensitive to the yellow-green wavelengths at about 570 nanometers. The range of energies to which it responds is remarkable: the unaided eye can detect a lighted candle at a distance of 14 miles and at the other extreme is able to resolve the details of a landscape flooded by 8,000 foot-candles of sunshine. (The amount of light falling on a surface is measured in foot-candles; the reflected light, or brightness, of the surface is measured in foot-lamberts.) These figures refer to the responses of the normal eye under ordinary conditions; the actual performance of the visual system will vary, of course, according to external and internal circumstances, including stresses on the eye or fatigue. The causes and mechanism of visual fatigue are not entirely clear, but it is known that the fatigue rate rises in direct proportion to the dimming of the visual field; in other words, the brighter the illumination, the less the eye tires. The fatigue rate is also affected, however, by other factors, such as the distribution, direction and color of the light.

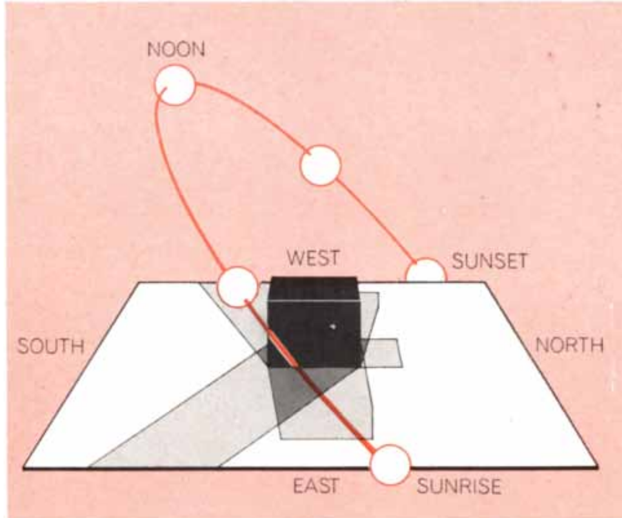
Generally speaking, the eye is most comfortable when the visual field has no great contrasts. This does not mean that it responds well to a field of uniform brightness; objects seen under diffuse light, for example, are difficult to make out. For optimal eye comfort the visual stimuli should vary somewhat in space and time but not strongly enough to produce stress. For tasks requiring fairly fine vision (such as proofreading, sewing or watch-repairing) the work should be illuminated by 100 to 150 foot-candles, and the surrounding surfaces should have a brightness of at least one-third of this value (35 to 45 foot-candles). Of course, many tasks require far higher levels of illumination: a surgeon at the operating table, for example, may need 1,000 foot-candles.

Apart from miscellaneous items of information such as these, the architect and the designer of illumination systems have little in the way of research findings on visual requirements to guide them in the creation of luminous environments for present-day needs. The questions that still need answers are numerous and important. It would be useful to know, for instance, if illumination should be increased as the day goes on and workers' eyes tire. What are the most effective forms of lighting for particular tasks? What is the optimal mix of natural and artificial illumination in the modern urban environment?

Illumination engineers tend to favor establishing complete control over the

FOUR PANES OF GLASS that modify daylight in different ways frame part of the midtown Manhattan skyline in the photograph on the opposite page. At top left is water-white glass; it absorbs no colors and transmits nearly 90 percent of the outdoor light. The other panes are examples of the wide range of "environmental" glasses available to architects today. The bronze-tinted glass (*top right*) transmits 51 percent of the light, the neutral gray glass (*bottom left*) 42 percent and the blue-green glass (*bottom right*) 75 percent. Environmental glasses also reject a large percentage of solar heat, thereby reducing the load on interior cooling systems. The glasses seen in the photograph are made by PPG Industries, Inc.

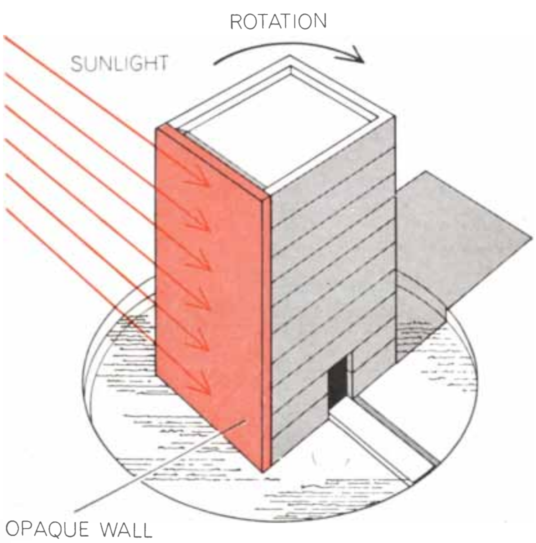


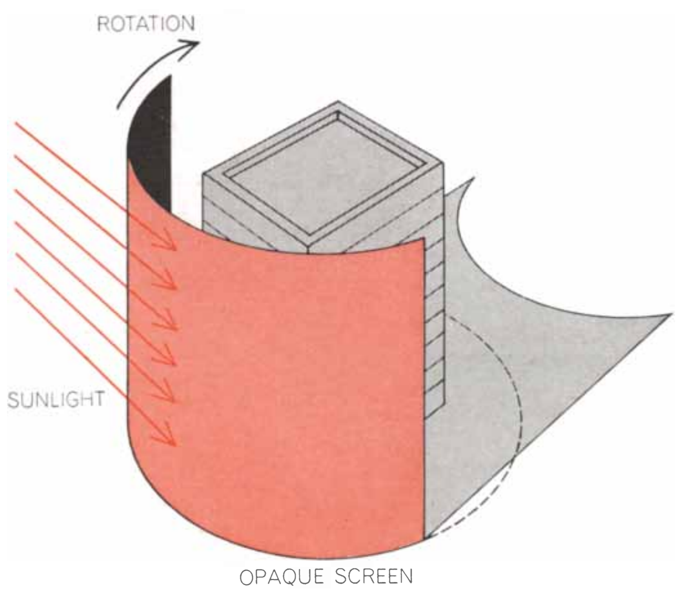


MOVEMENT OF THE SUN across the sky differs in azimuth and elevation with the seasons. The examples shown are summer (*left*) and winter (*right*) at 40 degrees north latitude. The seasonal variations alter the amount of solar energy that impinges on buildings.

luminous environment by employing fully artificial lighting in windowless buildings. For some functions this is obviously appropriate and essential. An outstanding example is the assembly tower at Cape Kennedy where the vehicle for the moon mission is to be constructed. In this structure (the world's largest building) the necessity for absolute control of all the environmental conditions is such that the enclosure must be hermetically sealed. For most purposes, however, the windowless building seems not only impracticable but also undesirable. Apart from the question of cost (involving the expense of the lighting system and the cooling needed to remove the waste heat it produces), people do not relish being cooped up in a windowless building. Human vision and well-being apparently suffer when vision is restricted to the shallow frame of man-made perspectives and is denied the deep views of nature. The eye wants variety in the optical conditions and freedom for occasional idle scanning of a visual field broader than the work at hand. In the home and at work people hunger for view windows, if only to "see what the weather is like outside." And in many activities windows serve an essential function, for looking out or in or for both; one need only mention stores, banks, lobbies and airport control towers. Although artificial lighting will inevitably come into increasing use, the windowless building will certainly remain a special case.

Let us begin, then, with the first consideration in the illumination of a building interior: the appropriate use of sunlight. For this an architect now has a large variety of devices at his command. The first step, of course, is suitable orientation of the building toward the sun, so that sunlight will be admitted through transparent walls where it is wanted or excluded by opaque walls where it is not wanted, and a maximum of indirect daylight can be obtained throughout the day in parts of the building where direct





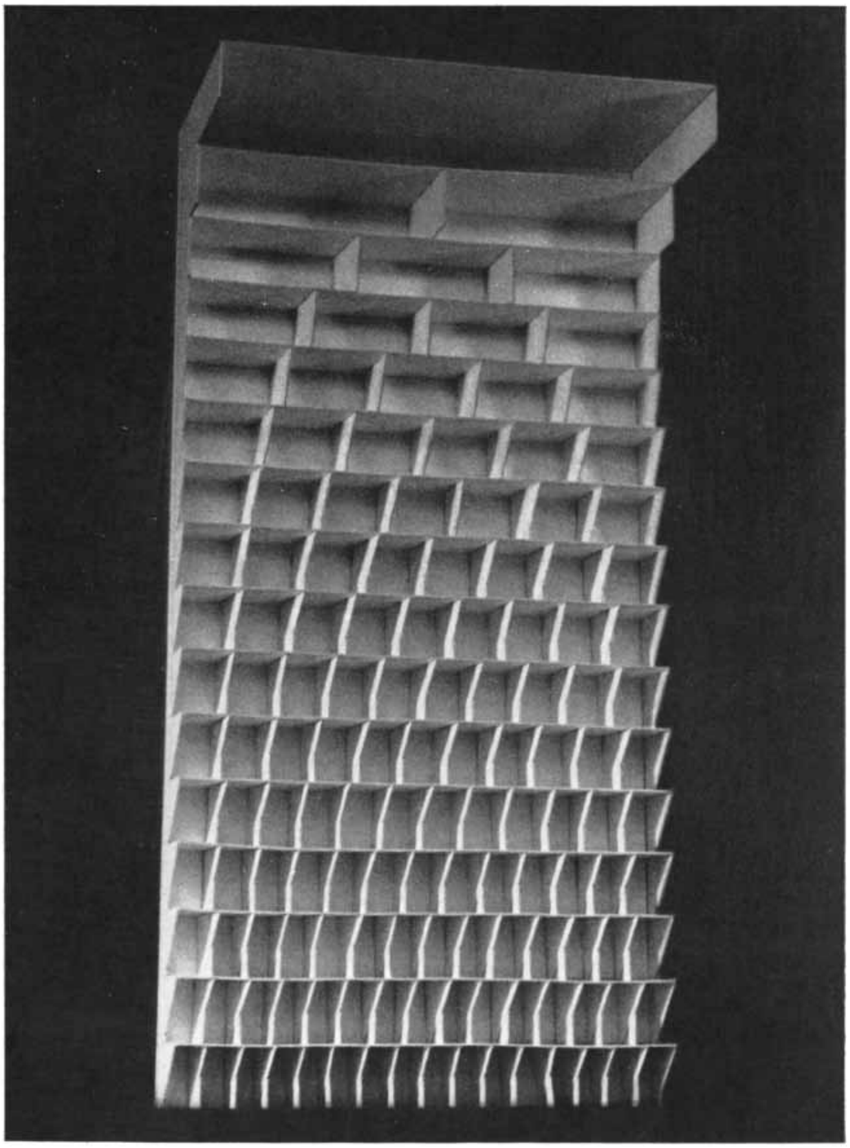
RADICAL SOLUTIONS to the problem of unwanted solar energy include construction of a revolving building (*left*) that would present the same windowless wall to the sun all day long, or a revolving sun screen (*right*) that would always intercept the sun's rays.

sunlight is undesirable. In regions of intense sunlight, such as the U.S. Southwest, or of feeble winter sunshine, such as the Canadian Arctic, effective use of the sunshine may be important not only for lighting but also for heating. Elsewhere, as in Lower California or the Persian Gulf region, cooling requirements demand that the building's interior be shielded from the sun. In any case, the orientation problem of course is complicated by the sun's movement across the sky and the seasonal variations in its angle. There are several possible means of coping with this movement. The building might be placed on a turntable that rotated it slowly in synchronization with the sun. Where the sunlight can be used for heating as well as lighting such a device might be economically feasible, particularly if an efficient and relatively frictionless turning apparatus were developed to minimize the power required to rotate the structure. Alternatively, the control of sunlight might be accomplished by a simpler mechanism: a solar screen that would run on a track and move around the building with the sun. It could be applied to large buildings as well as small and might serve as a windbreak in cold or stormy weather.

Both of these ideas, although still rather speculative, are actually extensions of a device that is already in fairly common use: namely, external sun shields consisting of large vanes that, like those of venetian blinds, can be changed in angle to keep out or let in sunlight as the sun shifts. With electronic controls these screens can rotate automatically in response to the sun's movement. They are particularly useful in warm, dry climates, where they are not subject to freezing or corrosion. Screens of this kind give far more satisfactory protection against the sun than the now common practice of building overhangs for windows, which often are more photogenic than useful because they do not allow sufficiently for variations in the angle of the sun.

Ralph Knowles of the University of Southern California has done some pioneering research on the surface responses of buildings to environmental forces—light, heat, gravity, air and sound. Using computerized techniques of analysis, he studied the surface response to light of structures in various shapes (cubic, tetrahedral, ellipsoidal and so on) and with various patterns of opaque walls. He concluded that rational parameters for the architectural control of sunlight effects and of other forces could be established. He is now studying the possibility of extending the same criteria to the modification of environmental forces not only for buildings but also for urban districts and even entire cities.

Knowles's approach is to use the structure itself as a means of manipulation and control of daylight. Since structural materials are necessarily opaque, the effectiveness of the system depends on the way the geometry of the wall itself intercepts direct light or admits indirect light. There are now, however, a wide variety of nonstructural surfacing materials of every degree of transparency that can be employed as filters. Even with ordinary plate glass one can obtain certain desired effects simply by adjusting the orientation or shape of the glass window. Curved glass that eliminates direct reflection of the bright outdoors can make a store window invisible for an observer looking in from the street; a glass wall angled from the vertical can likewise minimize disturbing reflections from indoor light sources and thus give a clear outward view, as in the famous Top of the Mark restaurant in San Francisco overlooking the city and the Golden Gate or the more mundane instance of airport control towers. Much more exciting, of course, are the effects now achievable with special glasses and other materials that filter, polarize, refract or focus light and thereby select the wavelengths of light to be admitted to the building or place the light where it is wanted.



GEOMETRY OF PROTECTION against unwanted solar radiation is studied by means of a model made at the Department of Architecture of Auburn University under the direction of Ralph Knowles. The design uses interlocking planes both to control the sunlight and to transfer building loads to the ground. J. H. R. Brady and D. L. Meador made the model.

CONTROL OF LIGHT AND HEAT is achieved at the Los Angeles Hall of Records by vertical louvers that resemble a venetian blind turned sideways. The angle at which the louvers are set is adjusted monthly to provide maximum shade throughout the year. Architects were Neutra and Alexander, Honnold and Rex, H. C. Light and James R. Friend.

The most familiar example—glass that is transparent to visible light but that blocks the infrared wavelengths—is now in wide use; in recent years it has been joined by new families of glasses and plastics that afford more subtle manipulations of sunlight.

One of the new glasses, coated with a thin film of metal on the inside face, acts as a one-way mirror, thus cloaking the interior of the building in privacy from outside observers in daytime while allowing the people inside to look out. (Actually on a bright day the exterior reflections on ordinary plate glass have much the same effect, making the interior almost as invisible to outsiders as if it were sheathed in polished granite.) The one-way mirror glass not only dispenses with the need for curtains or shades in daytime but also appears to be effective in blocking the entry of heat radiation.

A new type of glass now under development promises to introduce a novel mechanism for the management of sunlight. The glasses of this breed, called photochromic, are darkened by ultraviolet light, and oddly enough their reaction is reversible: as the ultraviolet intensity decreases, they recover their transparency proportionately. Hence the glass can maintain the intensity of the sunlight entering the building at a stable level. It should prove useful for classrooms, control towers, libraries and museums, where visual transparency is mandatory and a stable mix of natural and artificial light is desirable but difficult to maintain.

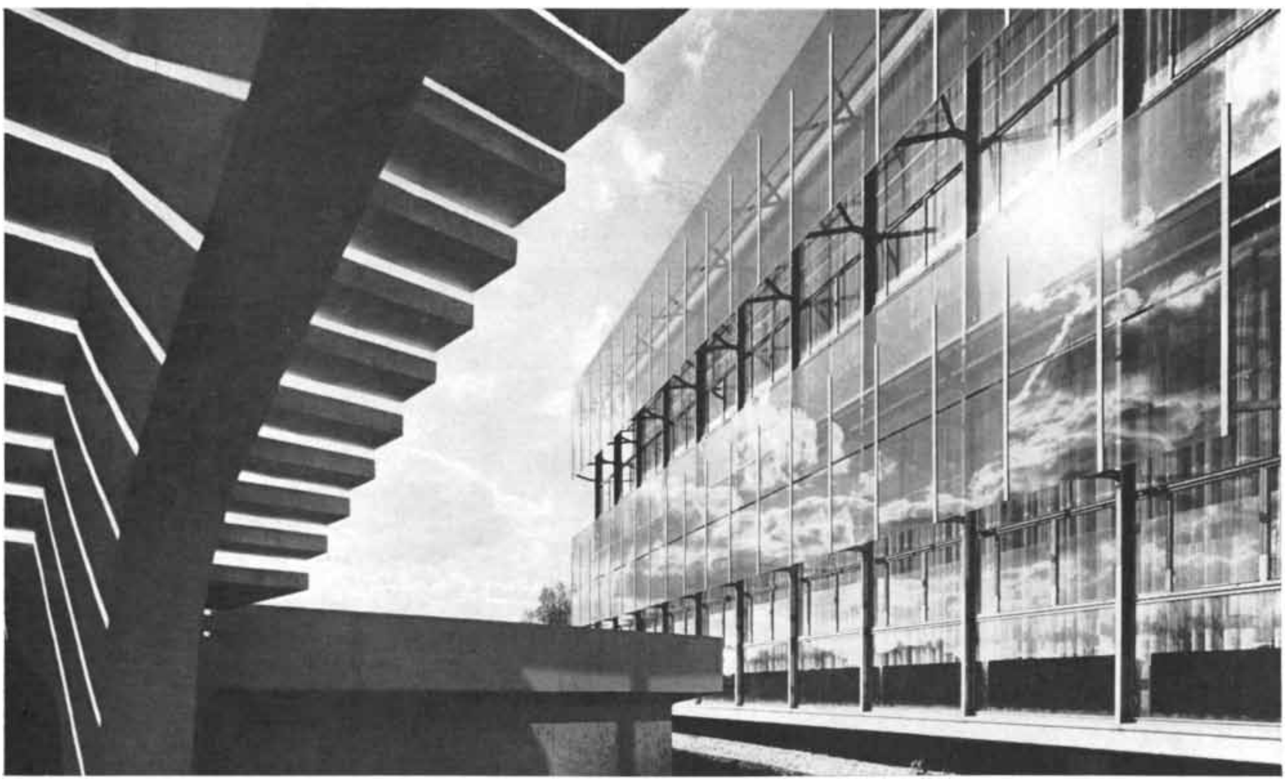
Another sophisticated innovation is embodied in a light-polarizing material formed by layers of plastics. It clarifies seeing and improves the efficiency of the use of light. Under ordinary illumination a surface is partly obscured by a "veil" of reflected light that tends to blur the colors and textures of the surface. Vertically plane-polarized light, which is absorbed by a surface and then reemitted, eliminates this veil and makes it possible to see the true qualities of the surface with greater ease and more accuracy. Polarized glass such as is used in sunglasses is not suitable, however, for purposes of illumination; it is effective only in certain directions, absorbs more than 50 percent of the light, is unpleasantly tinted and cannot be frosted to hide the light-bulb filament or soften the light. The new multilayer plastic polarizer avoids these shortcomings. The glare-reducing effect of this material on the illuminated surface varies, however, with the angle of vision from which it is viewed. Most desk work is done at angles between 0 and 40 degrees from the vertical, with the peak at 25 degrees, whereas the polarizer's most dramatic effects are from 40 degrees up, that is, in the field of middle vision. The plastic polarizer is not weatherproof and can only be used indoors, where it could serve well in ceiling fixtures and perhaps inside glass walls and skylights for daylight illumination of galleries and museums.

Another broadly applicable material for the manipulation of daylight is the so-called prismatic glass. Available in both sheet and block, it can deliver the incident daylight to any desired area of a room. It can be particularly useful for work that must be done under glareless light, such as matching colors, for illuminating paintings and for dramatic effects such as focusing a narrow beam of sunlight on an object—the "finger of God" effect that was cultivated by the baroque architects.

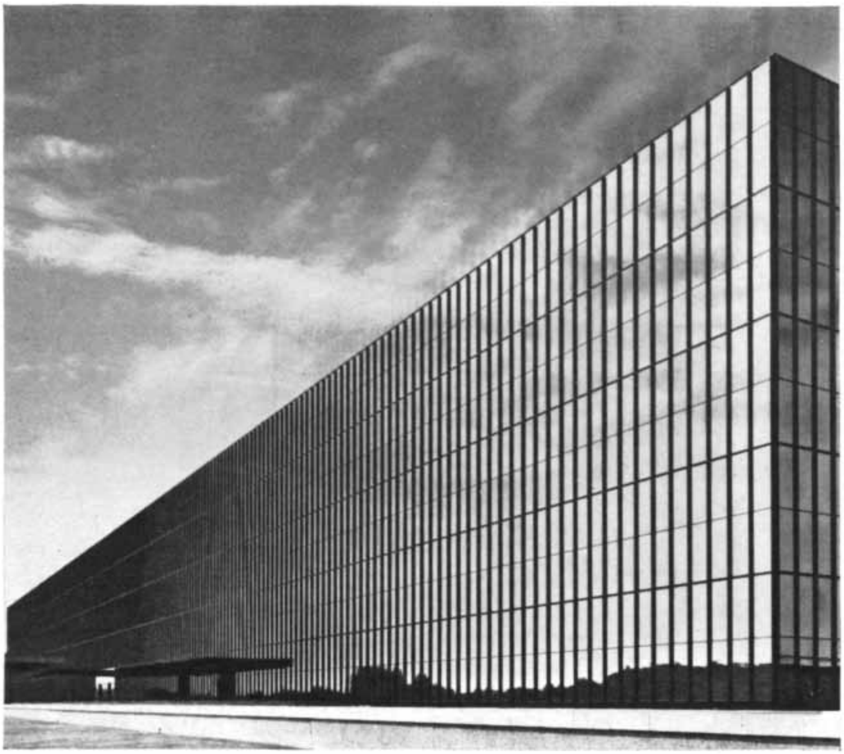
The sophisticated exploitation of sunlight is now more than matched by the ingenious exploitation of the possibilities of artificial illumination. Electricity, which in this century has supplanted all other sources of artificial lighting, has endowed us with an almost incredibly varied range of illumination devices. Lamps, fixtures, accessories, controls and methods of disseminating light are available in great variety, and their permutations and combinations run into the thousands. The list of ways that have been found to generate light by electricity is itself a long one.

The first electric-lighting device was the arc lamp, which jumps a bridge of luminous current across the gap between two electrodes. Much too hot and inflexible to be used in interior lighting, it is employed principally for motion-picture and television photography, for illumination of parking lots and playing fields and in large searchlights. The second-oldest electric lamp is the incandescent filament (now made of tungsten) enclosed in a sealed glass bulb. It is inefficient: only 10 percent of its energy output is in the form of light (the rest being lost as heat) and an additional proportion of the light will be absorbed by any colored bulb or filter that is used to modify its yellow-white color. The incandescent lamp is so flexible and convenient, however, and is available in such a wide range of sizes, shapes and capacities that it is still by far the most popular type for general lighting, and its efficiency has been improved nearly tenfold in recent decades.

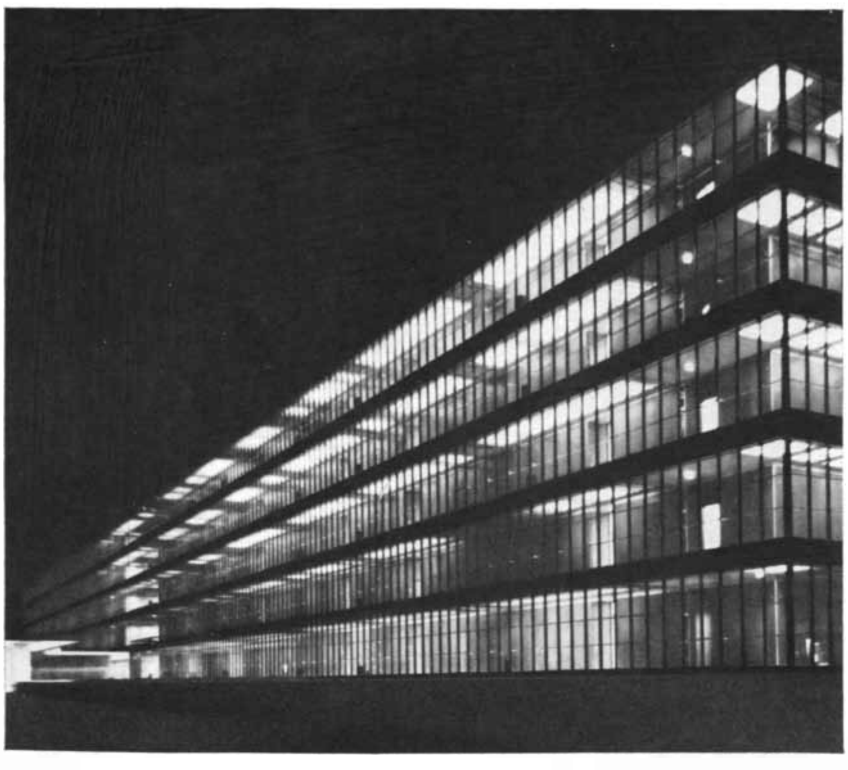
Artificial lighting is now largely dominated by the new and growing family of lamps based on the electrical excitation of luminous vapors, which already predominate in the fields of commercial, industrial and outdoor illumination. Sodium-vapor lamps, yielding an efficient output of 45 to 55 lumens of light per watt of power, have come into common use for the lighting of highways and bridges. Neon lamps in various colors, used mainly for signs, have become a ubiquitous—too ubiquitous—feature of the nighttime landscape. The most efficient of the vapor lamps are those employing mercury vapor; some produce more than 100 lumens per watt of power. Excited mercury atoms emit light at the blue-green end of the visible spectrum and into the near ultraviolet. Hence mercury-vapor lamps can be designed to serve as sunlamps, as light sources of high intensity or as fluorescent lamps, in which the ultraviolet emission from the mercury atoms is used to generate visible light from fluorescent material coated on the inside of a glass tube. The comparative coolness of a fluorescent lamp arises from the fact that mercury emits almost no energy at the red end of the spectrum and fluorescent emission itself possesses very little



SHADE WITHOUT SHADOW is obtained in the interior of the Van Leer Building in Amstelveen in the Netherlands by suspending horizontal panels of light- and heat-resistant glass at a distance from the southern wall of the building. Convection currents rise between the panels and the wall and help to dissipate the solar heat accumulation. The architects were Marcel Breuer and Associates.



OPAQUE IN DAYLIGHT, the glass walls of the Bell Telephone Laboratories building at Holmdel, N.J., are mirrors to an observer standing outside the building. The building's occupants, however, have a clear, shaded view of the exterior. A thin metallic film deposited on one surface of the glass acts as a mirror on the side that is most strongly illuminated.



TRANSPARENT BY NIGHT, the Holmdel building emits a glow of light once the level of exterior illumination falls below that of the interior. The interior walls are now mirrors to the occupants. The glass rejects nearly 80 percent of the solar heat load. It is made by the Kinney Division of the New York Air Brake Co. Architects were Eero Saarinen and Associates.

heat. A fluorescent tube is only about a fourth or a fifth as hot as the ordinary filament lamp. Moreover, it produces from 25 to 75 lumens per watt, depending on the color, and it makes available a wide range of color in lighting, including a close approximation of the daylight spectrum. The linear shape of a fluorescent tube does not necessarily limit it to linear applications. The tube itself can be bent into circular, square or spiral forms; it can be installed in parallel rows, in conjunction with appropriate reflectors and diffusers, and it can be made into a planar light source ("luminous ceiling").

Given the present variety of sources and of accessory means of disseminating artificial light, one has indeed a great range of flexibility for adapting its application to particular needs and situations. The problem of specifying and evaluating the requirements in given cases is of course highly complicated; every lighting problem involves a number of factors, subjective as well as objective. There are, however, a few helpful principles that seem well established.

The first is that, as I have already mentioned, good seeing demands a high level of illumination. Within broad limits, the more light there is on the visual task, the easier vision becomes and the less stressful the task is on the organism as a whole. The second "law" of good lighting is that all areas of the room should be balanced in brightness, with no great contrasts between adjacent surfaces. The visual field surrounding the task should be at least a third as bright as the task itself and no part of it should be much brighter than the task. The third principle is that it is important to avoid glare, either from the light source or by reflection.

The optimal levels of illumination for specific visual tasks have not by any means been finally established; the recommended levels have steadily been raised over the past half-century and may well go higher still. Tasks that were once performed at only 10 to 15 foot-candles are now believed to call for 100 to 200 foot-candles. For certain fine seeing tasks, such as microsurgery and autopsy, illumination as high as 2,500 foot-candles is recommended. Incidentally, as illumination levels rise, the generated heat becomes more and more of a problem. In a space under 100 foot-candles of illumination the heat from the lamps may account for 37 percent of the load on the air-conditioning system in summer, and at the level of 400 foot-candles

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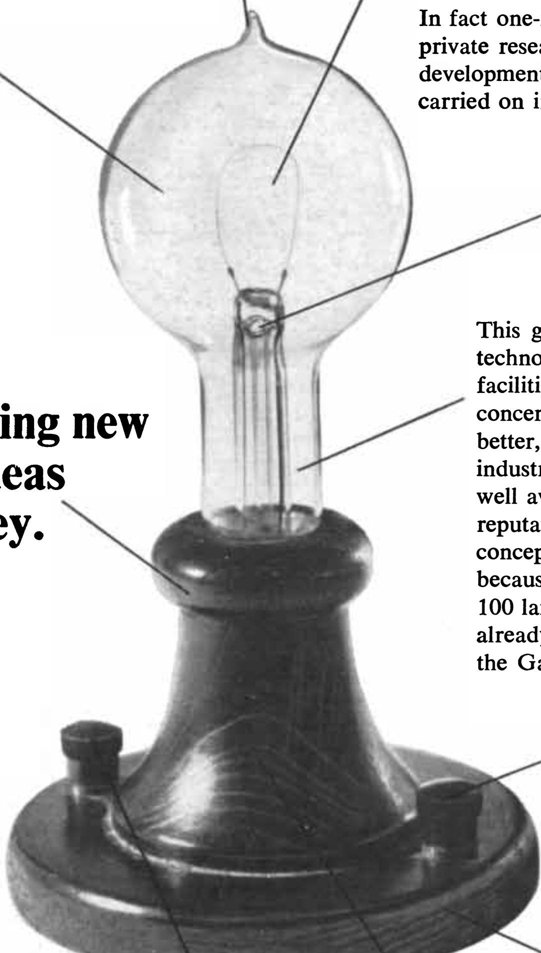

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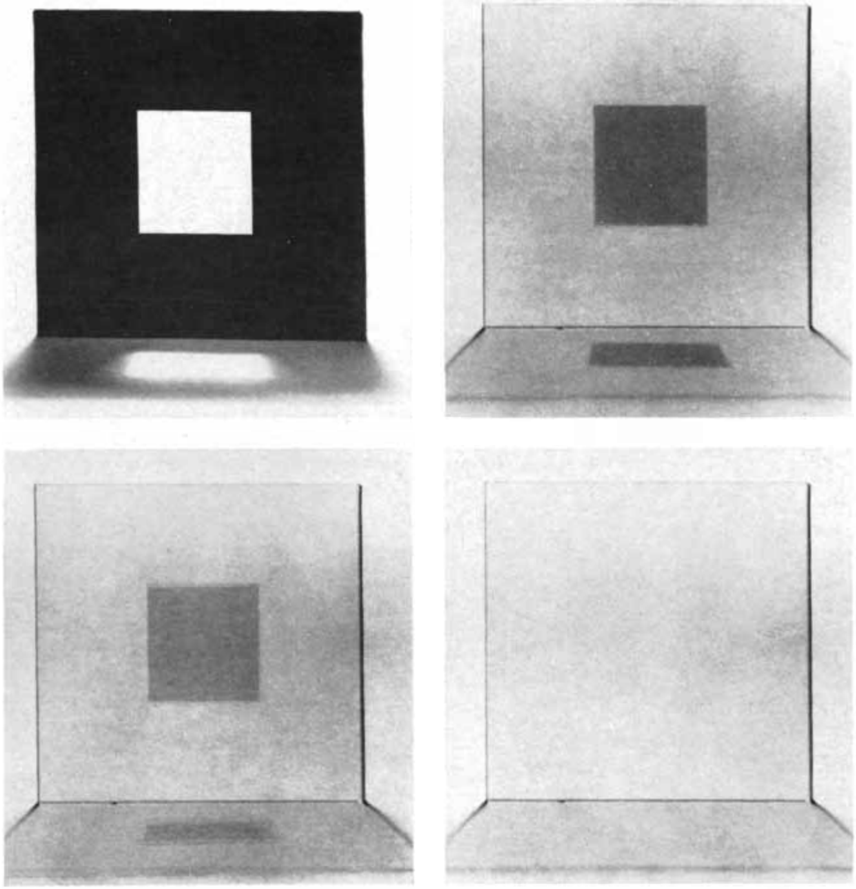
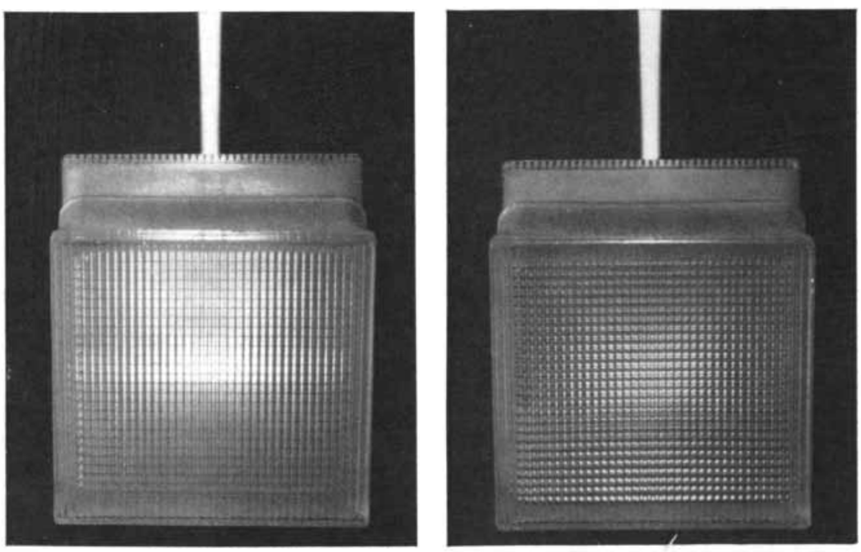


SELF-DARKENING GLASS contains microscopic crystals of silver halide that react to near-ultraviolet wavelengths by absorbing as much as 75 percent of visible light. A masked pane of the glass is exposed to sunlight (*top left*). Its unmasked central rectangle darkens immediately (*top right*). Screened from further exposure to ultraviolet, the darkened area begins to fade; in five minutes it transmits about half as much light as the unexposed area (*bottom left*). In half an hour the darkened area has vanished (*bottom right*). Known as photochromic glass, the light-responsive material is made by the Corning Glass Works.



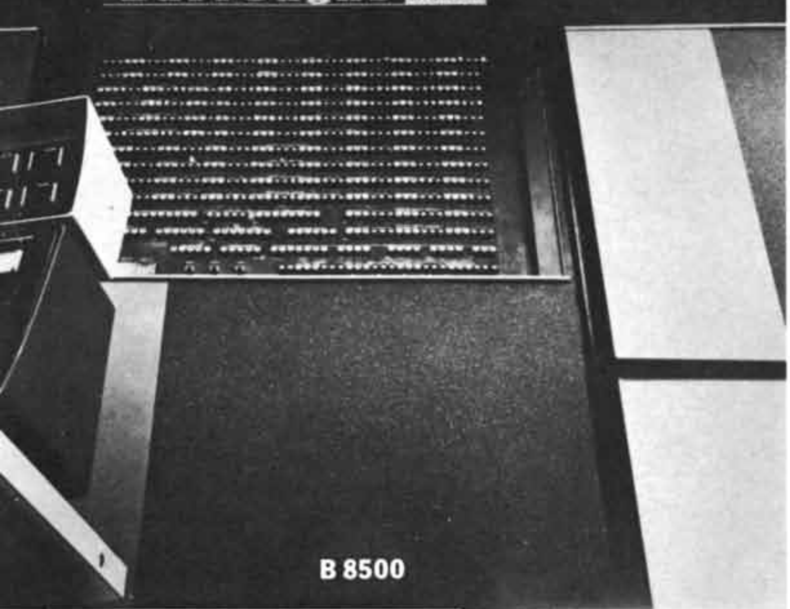
GLASS BRICK provides the architect with a translucent medium for bringing daylight indoors. At eye level or below, brick that acts as a general diffuser of daylight (*left*) is a practical wall material. Above eye level, prism-surfaced brick directs entering light up to ceilings to provide overall daylight (*right*). Bricks are made by the Pittsburgh Corning Corp.

the contribution to the cooling load may rise to 70 percent. When waste heat reaches such proportions, it becomes a major factor in summer cooling. By the same token, it can be employed in winter heating, sometimes to the extent of becoming the entire source of heat. In these installations current practice is to siphon off this heat before it enters the conditioned space, either exhausting it in summer or feeding it back to the heating system in winter. Since such installations usually involve fluorescent tubing used in luminous ceilings, there is less waste heat and less of it is radiant. As much as 76 percent can be siphoned off directly into the return air system.

For many lighting problems, particularly on the macroscale, there are no readily determinable criteria, nor have they been given much systematic study. The illumination of retail stores and showrooms, for example, involves subtleties in dramatizing the qualities of the merchandise. (Obviously jewelry and automobiles need point sources for shine and glitter; furs and velvets show up best under floodlighting at acute angles.) Restaurants, bars and cafés have their own special lighting needs; so do art galleries and museums, theaters and churches, exposition buildings and pleasure gardens. Whether or not the purely intuitive approach in creating "effects" in these situations produces truly effective results is a moot question. The vogue of "mood" lighting in restaurants and cafés, where current taste seems to dictate that the illumination level be low and the color pink, has the unfortunate effect of making one's companions only dimly visible and laying an unappetizing patina on food and complexions.

Just as a blind architect would be a contradiction in terms, so too would be a completely lightless room (tombs and photographic darkrooms would be among the few exceptions). All designed spaces are conceived in visual terms. Many of the architect's decisions as to interior proportions, colors and textures actually deal with matters of surface response to light. They are all made with an eye to "how it all will look." Such a conceptual approach assumes that a stable luminous state is desirable, that the room will "read" the same way day and night, winter and summer.

In any windowless enclosure this is a simple matter, but in any room where glass plays an important role the situation is entirely altered. Such transparent membranes are conceived as (1) being a source of light and (2) affording visual access to an illuminated outdoors. With



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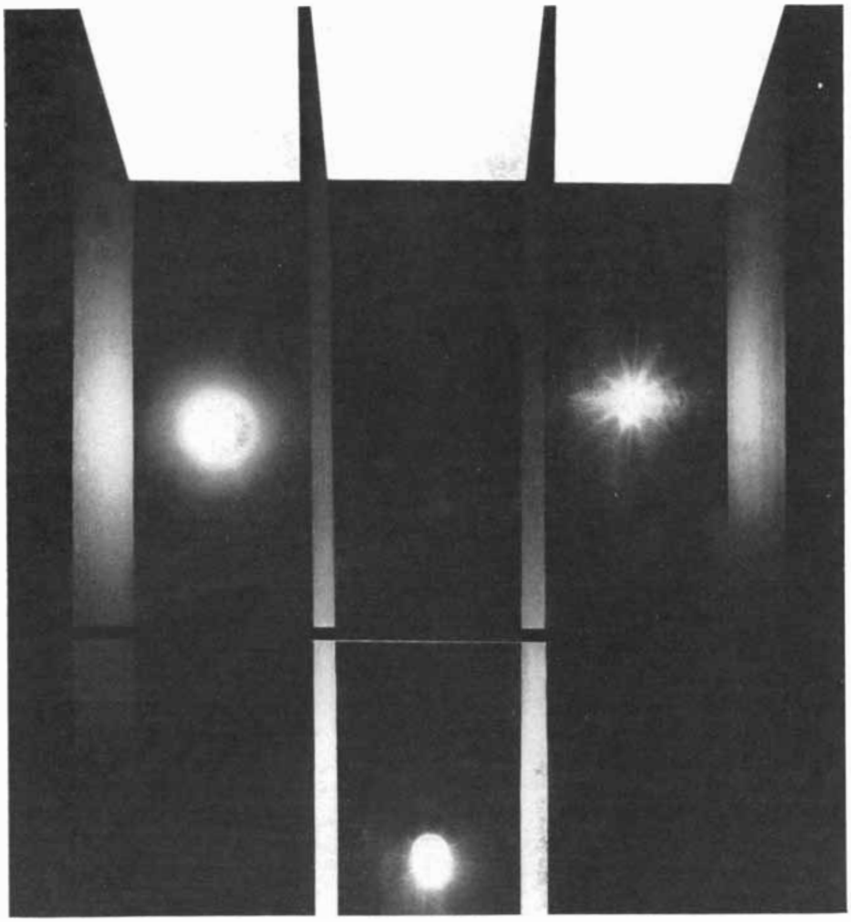
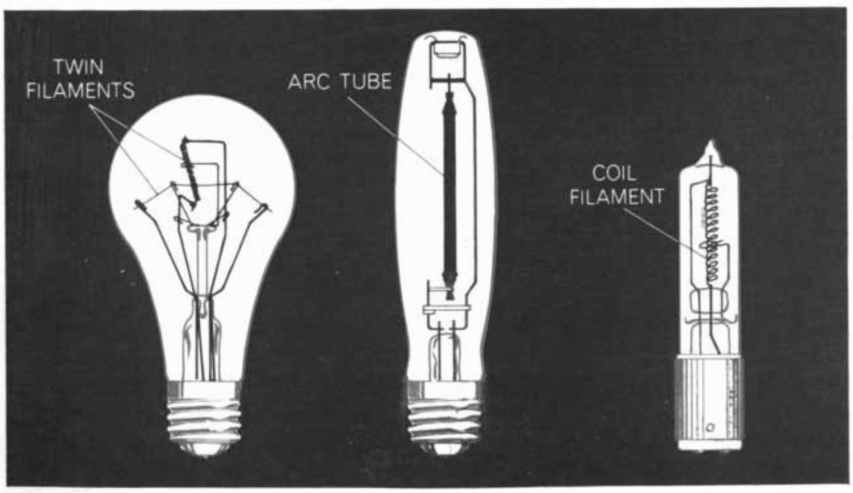


IMPROVEMENTS in new kinds of lamps include an increase in light emission per watt input and longer life. Two new lamps are compared here with the familiar incandescent household lamp (*left*). All three are drawing approximately 250 watts; distance of each lamp from the equally illuminated targets indicates its light output. This is 16.5 lumens per watt for the incandescent lamp, more than 80 for the sodium-vapor lamp (*center*) and 17.5 for the tungsten halide lamp (*right*). The tungsten halide lamp has a 2,000-hour life expectancy.



ANATOMY OF ADVANCED LAMPS is compared with that of a two-filament, three-way incandescent lamp (*left*). In the high-intensity sodium-vapor lamp (*center*) the vapor is contained in a translucent ceramic tube sturdy enough to allow operation at a temperature and pressure that spread the sodium-emission wavelengths over most of the visible spectrum. The filament of the tungsten halide lamp (*right*) is sealed in a quartz tube containing iodine gas; evaporating tungsten reacts with the gas and is redeposited on the filament, thereby increasing its life. The lamps are the ones shown in the photograph at top of page.

nightfall, however, both of these conditions change. Surfaces that were a source of light become open sluices for its escape, and the lighted outdoors is replaced by a dimly mirrored image of the room. Traditional architecture had no real difficulty with this paradox. Although natural lighting was very important, the high cost of glass and of heating tended to keep windows small or few. And since the windows were always covered at night with curtains or blinds whose reflectance value approached that of the walls, they did not seriously affect the luminous response of the walls.

In modern architecture, with its wide use of glass walls and wide misconceptions of their optical behavior, the problem of nocturnal disequilibrium reaches serious dimensions. In such cases the interior can only be restored to its daytime shape by one of two measures: (1) by covering the glass with a reflective membrane (shade, shutter or blind) and (2) by raising the illumination level outside the glass to that of the room itself. Both measures are technically quite feasible, although for obvious reasons the first is likely to be the simplest and least costly.

The uninhibited excursions in lighting at recent international expositions have demonstrated the great variety and brilliance of lighting effects that are now available through the use of color, both luminous and pigmental. There is a large and growing literature on the alleged subjective reactions to color. We are told that red is exciting, purple is stately or mournful, yellow is joyful, green is calming, and so forth. There are even reports on experiments in the therapeutic use of color for treatment of the mentally ill. The University of California at Los Angeles psychologist Robert M. Gerard, working with normal adults, has found that as a general rule people do indeed show differential responses to different colors. Red light apparently brings about a rise in blood pressure, respiration rate and frequency of blinking; blue light, on the other hand, depresses activity. He concludes that the entire organism is affected by color, that different colors evoke different emotions and degrees of activity and that activity rises with increases in the wavelength and the intensity of the light.

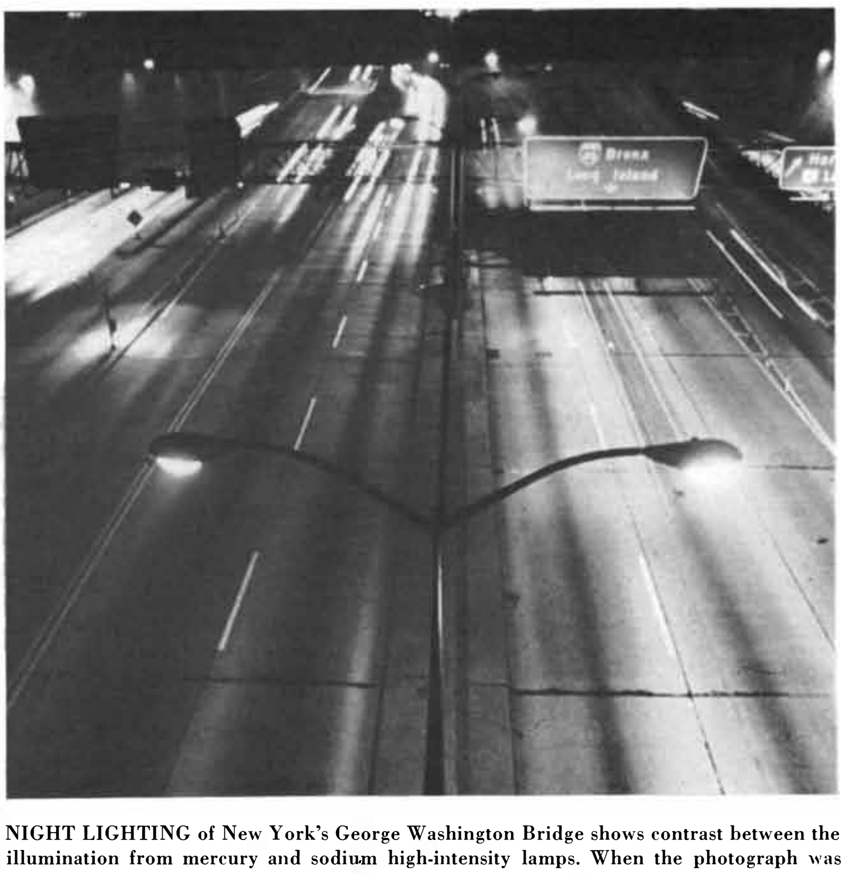
Nighttime illumination of the outdoors by artificial light is another factor with a profound potential for affecting human life and activity. It is hard for us to imagine how great a transformation of living was introduced by this development. In preindustrial times nightfall

brought general movement and activity almost to a complete halt. For understandable reasons about the first application of gas and electrical illumination was for streetlights. The illumination of the urban environment at night doubled the daily period of mobility and activity for city dwellers. Moreover, it added a totally new aspect to the urban landscape.

Outdoor lighting has been carried further in the U.S. than anywhere else in the world; if not the best lighted, American cities are the *most* lighted on earth. Seen from the air on a clear night, with their structure vividly diagrammed by millions of lamps and illuminated signs, they are beautiful. Unfortunately at ground level the beauty and the clarity disappear. Grotesquely disparate in size and brightness, jostling one another in crowded profusion, garish and discordant in color, the lamps and signs are confusing to pedestrians, dangerously distracting to motorists and annoying to residents who must live in their nightly glare.

There are models showing how cities and their contents can be illuminated with highly aesthetic effects. The skillful lighting of the areas around Westminster Cathedral in London and the Louvre in Paris, of the Capitol in Washington and the Acropolis in Athens and of châteaus and gardens in France illustrates the possibilities in the urban use of illumination for spectacle. Most of these places are of course empty monuments. For inhabited areas of the city, designing systems of street and landscape lighting that will be functional but not disturbing to the residents is a more difficult and delicate matter. With skill and imagination, however, it should be possible to illuminate buildings, neighborhoods and the entire city in ways that will serve and satisfy everyone.

It is apparent that the nature of the luminous environment exerts profound physiological, psychological, social and economic effects on life in our urban culture. So far neither the effects nor the possible means of ameliorating them have been adequately analyzed. Obviously the establishment of a harmonious relation between man and his new environment of artificial illumination calls for cooperative studies by physical and biological scientists, engineers and architects.



NIGHT LIGHTING of New York's George Washington Bridge shows contrast between the illumination from mercury and sodium high-intensity lamps. When the photograph was made, lamp standards over outbound lanes (*left*) contained 400-watt mercury-vapor lamps and those over inbound lanes (*right*) 400-watt sodium-vapor lamps. The illumination of the inbound lanes is two to three times brighter than the illumination of the outbound lanes.