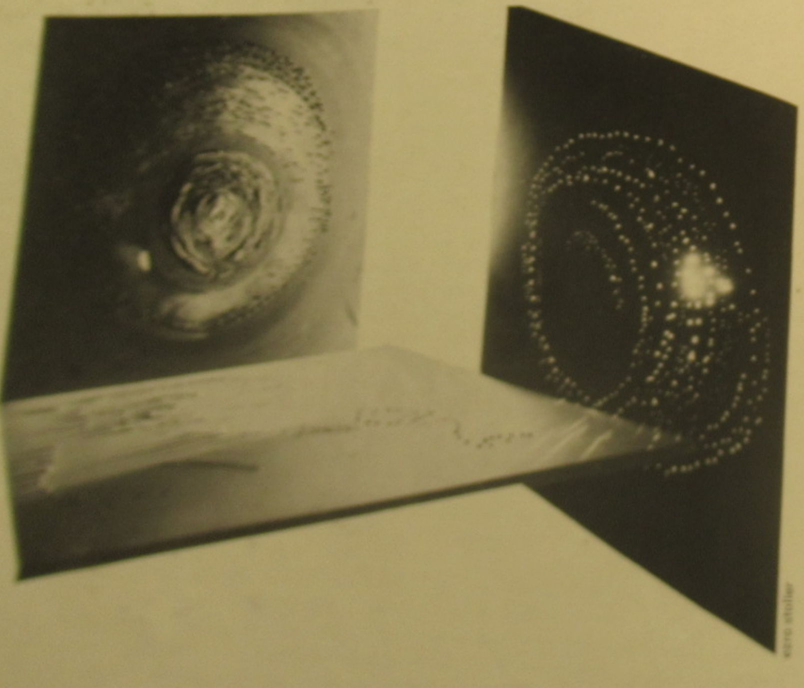
LIGHTING

its service and its spell



ezra stoller

part 1 of a two-part lighting study

ezra stoller

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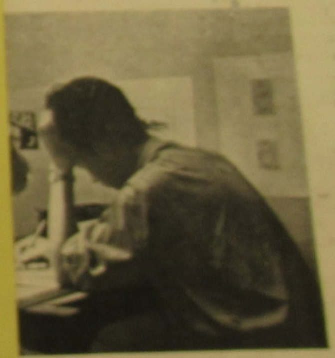

LIGHTING

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The attitude that lighting is part of the business of design is hardly revolutionary any more; and should, by rights, never have been; for light is what determines the composition of an interior at the time it becomes important, which is when it is seen. Light is, with today's technology, almost as manipulable as a sculptor's chisel, and can form and shape the same interior into quite different effects and moods; see, e.g., the photographs of the three UN council chambers on page 47 of last July's *Interiors.*

Nevertheless, evidence persists that lighting has been more or less thrown in after the job, even an expensive job, is done; disturbing spills of light that make an interior not at all the one its designer meant it to be; or a wan monotony, dwindling whatever interest there might have been; or good architectural details must be searched out in unlit corners, and so are missed altogether; picture windows become disconcerting mirrors at night when nothing is seeable outside.

The illuminating engineer is no dispensable entity, for one person cannot always be two things, or does not want to be. But if there is to be encroaching, the designer certainly ought to do it; for the engineer's job is primarily a technical one, and the mechanics of accomplishment are never of direct importance; results, with which the designer concerns himself, are.

Engineers *have* gone into heavy research about comfortable and effective lighting for good visibility, and their findings are certainly of concern to the designer. But the engineer and the designer usually have different viewpoints. One starts his proceedings with the assumption that people are involved in the practicalities of life, the other imagines his benefactees just as often in conditions of the spirit; one, in his researches, usually expects people to be using their eyes for examining detail, the other begins with the attitude that they will be using them for less trying purposes, such as seeing his wonderful design, if we may be so blunt. Not all the time, of course; it is possible to find engineers who will permit an interesting shadow, even in an office, and designers who think their clients may read sometimes. And wise men in each camp recognize the interdependence of physical and psychological comfort; a pale, scientific sameness can be almost as distracting to a mildly sensitive clerk as an envelopment of shadow, and, on the other hand, color rhapsodies on the walls are delightful only so long. It may be regrettable that the body's demands are not so fancy as the soul's—that a banana split should be indigestible, and that a dramatic interplay of spotlight and shadow should not contribute to productivity in a drafting room. But physiological fact is not only harsh, but real, so we will bend to reality in these pages when we must, which, for a while, will be fairly often, since it takes some words to talk about the aspects of physiology, mostly the eye, that relate to our subject, and the technology that has been developed to satisfy physiological needs. All the while we do so, though, the feeling will lurk in the backs of our minds that we are not being supremely realistic, but only pragmatically so; because, though we do have livings to make and figures to add and overall even lighting schemes to not displease our working eyes, we should recognize that those figures and evennesses are only instruments to things of immediate worth, one of which can be an ennobling, or an entertaining, interior.

bacci attilio

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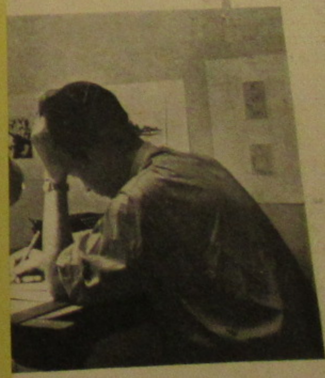


IGHTING

its

the author

John Anderson is no illuminating engineer, nor physiologist, nor physicist, which partly accounts for his ability to translate these experts' technical jargon into *Interiors'* language. His insight into the whole spiritual truth of the extremely complex, important subject of lighting is, however, beyond our analyzing in terms of his history, which he recounts thus: Born and raised in Minneapolis, he spent one-and-a-half years in the Army without any significant experiences, went on to major in English and History at the University of Minnesota, immediately after entrained for New York, walked into *Interiors'* offices cold, landed a job on the strength of a writing chore an editor handed him in order to get rid of him. We suspect more. *For Your Information* is his department.

A lot of the text, some of the planning, research, and creative thinking, and most of the drawings in both parts of our Lighting Study were done by Aldo Giurgola, our acting Art Director. Because he designed this month's cover, and also because he refuses to allow us to use his portrait twice, we must refer the reader to our *Cover Artists'* page (8) for a note about this young architect, whose remarkable career we have outlined in the barest form, without the superlatives obviously in order.

[illegible]

A view into Lever House from across the street lays bare the useful side of light as you raise your eyes from the bottom floor, where you see what fine work light is doing, to the top, where you see what light is coming from. Lucio Fontana's "spatial conception" on the opposite page is more subtly symbolic, expressing those less tangible aspects of light the designer cares most about—its evocativeness and its capacity to be a positive pleasure.

Mosaic, Sant' Apollinare Nuovo, Ravenna

The Byzantines wore shining robes, glittering, of unreal luminosity, in resplendent processions inside their churches. Glass and translucent marble particles of brilliant mosaics glowed in myriad reflections.

900

LIGHT

SHADOW

The earliest means of producing artificial light were torches, candles, oil lamps . . . and the modest amount of light shed by any one source was sufficient only to sunder the darkness . . .

Hence the only great light, for centuries, was natural light, the light that came from the sun. Men worked during the hours when it shone. When darkness fell, they sought rest.

The flame of the torch, of the candle, and the lamp, was in constant motion, and it cast powerful, fearful shadows.

These primitive tools determined the existence of shadow as the main suggestive fact of interiors.

The alternate play of light and trembling obscurities established an immediate sense of the presence of the unknown, a constant awareness of the mystery of the infinite . . .

For this play was restless, and the evocative mood it aroused had a quality very different from the abstract atmosphere of places where the light floods in everywhere.

The static symmetry of Romanesque structures was pointed by modest, rythmically spaced lights reflected by the light colors of the frescoes. Almost all Italian churches of the 10th and 11th centuries were painted inside with the wonderful stories of the Faith, from the ceiling to the floor, and these were light itself.

1300

When shadow invaded the Gothic cathedral flames of the lamps and torches concentrated the light in the lower part of the nave, leaving above an unexplored d while the rays fled along the pillars and rib with no rest on into the black vastness, the interior seeming thus to melt into that endless space where is God.

San Giovanni in Zoccoli, Viterbo

1000

1300


St. Lorenzo in Florence, Brunelleschi

1700

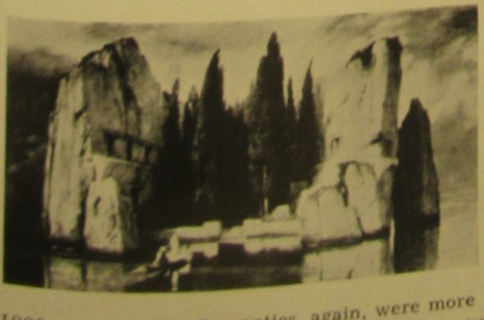
There was a time when darkness was unendurable, the age of the *Roi Soleil*. Life could be lived only in light—reflected by crystals, panes, mirrors, gilt, and white, ornaments of light enamels. The wallpapers with which the French then lined their houses were pale-tinted.


Royal Palace, Milan, 18th century

Brunelleschi and Bramante are the Renaissance; their architecture is the architecture of light, their structures crystals without time. The purpose of the flame was not merely for seeing in darkness, but to inundate the interior with light, destroying the darkness with hundreds and hundreds of sources, satisfying a need that no one had ever felt before.

1600 →

The Baroque is knowledge and control of the irrational . . . Its architecture is perhaps the only one that was conceived as a masterpiece of light effect. We can catch very little of its spirit in this day, when the huge interiors are alight with electric bulbs . . . The Baroque shadow was a described mystery; light from below, caught and reflected by cornices, projections, domes, and vaults, was carried in many directions in a wonderful balancing of focal points. Never was light more properly used as an architectural element itself. . . . And it penetrated outside the building too, to make the architecture alive in the night, among the stars of creation.

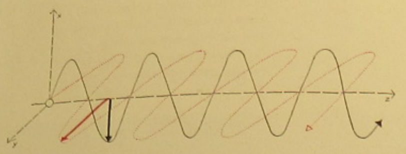

Island of the Dead, Boecklin

1800

The Romantics, again, were more concerned with darkness than with light, but their darkness led to death rather than to the infinite, was a finality, a falling curtain.

Light is today a positive force capable of bidding us, by scientific means, to be active, productive, or relaxed . . . Some day we will understand the shadow, and from that day we will know how to make light more beautiful.—*A. G.*

1 Radiant Energy



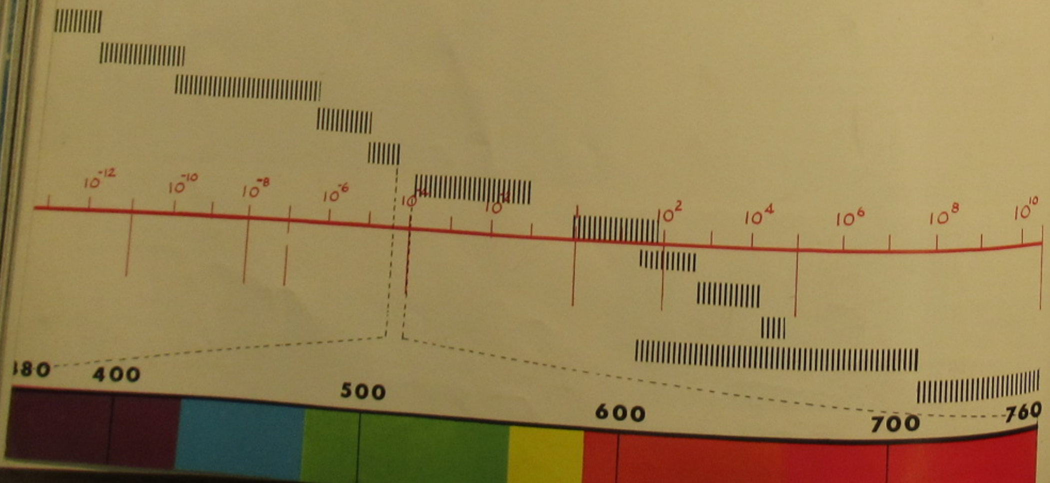
It is pretty cold comfort to look it up in Funk and Wagnall's and find light defined as "That form of radiant energy which is capable of acting upon the eye in such a way as to make visible the object from which it comes"; for one is not readily at ease with the word "energy," even when he knows what it means. Energy is a capacity, an ability to do work, which ultimately means, to cause motion. Radiant energy is one of several forms energy may take; in inadequate language, it is energy traveling through space.

A number of theories have been advanced about the means light, or radiant energy, travels by. Newton's corpuscular theory held that luminous bodies ejected particles which stimulated the optic nerves. Huygens' wave theory maintained that vibrations in luminous bodies are transmitted through ether, an all-pervading medium, in waves like ripples in water. Nowadays, two theories, each of them a modern form of either the corpuscular or wave theory, are taken most seriously, and though at first sight they contradict each other, they are both considered acceptable, since one or the other can explain certain phenomena the other is at a loss about. Their differences arise from the methods of examining light; under some measuring apparatus, light appears to be a wave function; under others, particles are evident.

The electromagnetic theory, which is a modern wave theory, improves on earlier ones in that it describes more fully the propagation of light, and foregoes the concept of ether, today considered unnecessary since its existence cannot be proven. If you will settle for oversimplification, this is how it goes: Vibrations of electrons in matter, such as in the sun or in an incandescent filament, create electric and magnetic fields in space, which oscillate in planes perpendicular to one another. An electric and a magnetic field together constitute an electromagnetic wave, which carries radiant energy. The drawing above represents such waves, showing the perpendicular directions of stress of the electric and magnetic fields, and the propagation of energy in a direction perpendicular to both those fields.

Wave lengths vary, and light waves are only a few of a vast range. In the entire electromagnetic spectrum represented by the red line below, the numbers above the line show wave length in centimeters; light waves, those from 10^{-4} to a little past, are remeasured, in the *light* spectrum at bottom, in more convenient millimicrons (a million millimicrons make a millimeter, and some 25 millimeters make an inch). The reason waves of these lengths are called light waves is, of course, because they are the ones that happen to stimulate our eyes. Other radiant energy wave lengths, represented by the black bands, are called what *they* are only because of their action on particular kinds of detecting devices; from top, they are cosmic rays, gamma rays, X-rays, vacuum ultraviolet, ultraviolet, infrared, radar, FM, television, short wave, broadcast, and power transmission. Each light wave has a certain color associated with it; violet light has the shortest wave length, red the longest, and the greens and yellows are in the middle, which makes it reasonable to expect yellows and greens to be most easily recognized of all colors under low illumination, as they are. White light is composed of all light wave lengths; passing of a ray of sunlight through a prism will produce the full color spectrum.

One of the reasons the electromagnetic theory is well regarded is that the speed of electromagnetic waves was discovered (by Maxwell, the developer of the theory) to be exactly the speed of light in air, about 186,300 miles per second. The particle, with Einstein behind it, has been restored to grace in a modern corpuscular theory of light, called the "quantum" theory. We will leave it only mentioned; the electromagnetic theory can provide quite satisfactory explanations of those characteristics of radiant energy that are of chief importance for artificial lighting.



2 COLOR

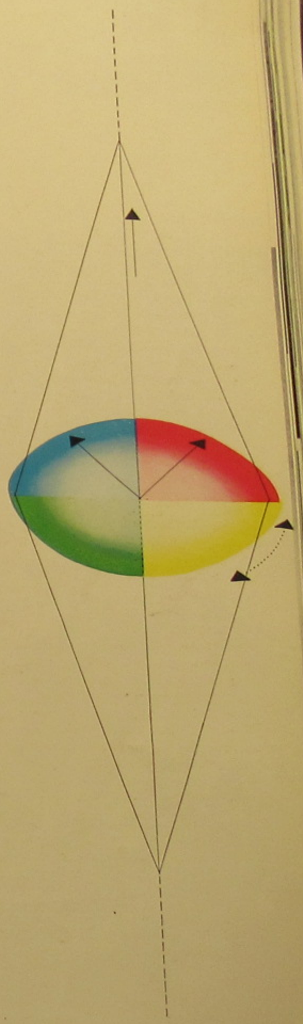
Color and its attributes, hue, saturation, and brightness, can only be recognized by referring to your sensations, so you see they are largely psychological matters. Red and yellow and other distinct colors are hues; saturation is the degree of a hue's vividness, its departure from gray; brightness, or brilliance, is the degree of resemblance to white or difference from black. The color solid at right shows these different aspects. The vertical axis represents brightness, with gradations from median gray in the center to white at the top and black at the bottom. Hue is shown cyclically, and saturation radially from the gray axis to the edges of the diagram, where hues are fully saturated.

Unless we indulge in pure fancy, psychological perceptions have physical correlates. Color as a physical thing is determined by both pigment and light. You know all about pigment being the color actually in a material, and about its primary colors—yellow, red, and blue, called primary because they are not composed of any other colors. By mixing them in certain proportions, any other color can be produced, through a subtracting process; blue pigment subtracts some yellow out of yellow, and at the same time yellow diminishes the blue, and green results. When all colors are combined, they are all subtracted away and you get black.

The primary colors of light are green, red, and blue, and judicious combinations of them can produce all other colors. In light, color mixture is an additive process, a combination of the wavelengths of red and green (for instance) producing a total effect of yellow on the eye; their separate wavelengths do not combine into one wavelength.

Pigment absorbs all other wavelengths than those carrying the hue corresponding to the pigment color. When white light falls on a red surface, all other wavelengths than the red ones will be absorbed; the red will be reflected, making the surface appear red. If green or blue light is put on a red surface, the surface appears black, since there are no wavelengths common to both red and either blue or green. Actually, some light will always be reflected, because both pure pigment and, especially, pure light color are extremely rare. Colors appear less saturated, but brighter, under strong white light than under lower illumination; unless the illumination is too low for the cones in the eye to function, when color is hardly seen at all.

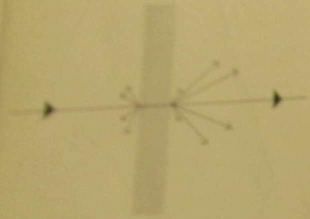
Human senses are much better at recognizing relative values than absolute ones, and the eye exaggerates adjacent color and brightness differences. If all your environment were of a single hue, no matter how saturated, you would not be aware of color, but only brightness.



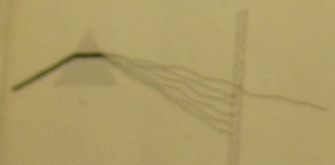
specular reflection

spread

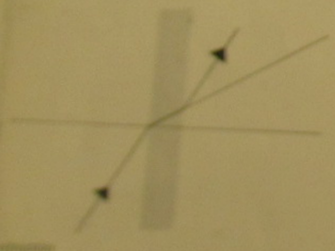
diffuse



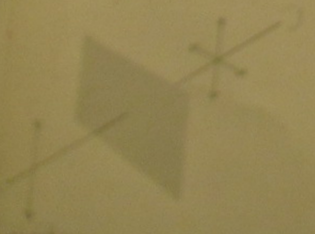
transmission



refraction through prism



refraction



polarization

3 CONTROL

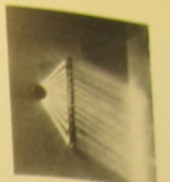
When it is unguided or uninterrupted, light travels in straight lines, as some ancients reasoned when they couldn't see, as they could hear, around corners. This dependable facet is of primary importance in adapting light to human purposes, not only because it simplifies the processes of getting light in the right places and making things look the way you want them to look; but also because it makes the direction, intensity, and visual character of light liable to control by merely putting a certain kind of material in its known path. A number of things may happen to light waves when they strike a surface. In reflection, the rays are redirected on the same side of the surface as that on which they fall. If the surface is perfectly smooth, the light is reflected specularly, which means it is redirected off at the same angle from the normal (perpendicular) as it struck. A mirror makes a fine specular reflector.

Spread reflection occurs when light falls on a fairly rough surface, the rays reflected in the same general direction as they would be were the surface polished, but spread into somewhat varying angles. When a surface is so rough that its particles are in different planes, diffuse reflection is what happens. Incident light rays, still individually acting according to the law of reflection, disperse in all directions. It is seldom possible to get a perfect 180° diffusion, but flat paints and other mat finishes can be good diffuse reflectors.

Most materials produce a combination of all three types of reflection.

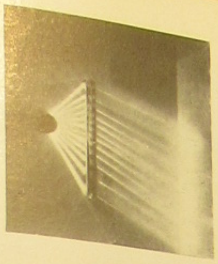
Refraction is the activity of light when it enters a medium of different optical density than a previous one. All transmitting materials have an index of refraction based on their optical density as compared with the density of vacuum, which is given an index of refraction of 1. The greater the difference in density between two adjoining media, the greater the angle formed by the ray at the point of incidence. If a ray passes from a rarer to a denser medium, it slows down and bends toward the normal; when passing from a denser to a rarer medium, it is accelerated and bends away from the normal. The angle of a ray's path through changing media is determined by the angle of the incident ray with the normal, the wavelength of the wave concerned, and the ratio of the indices of refraction of the media concerned. When a medium with regular and parallel surfaces on opposite sides, such as a sheet of glass, is interposed in the path of a light ray, refraction is neat and orderly, the ray continuing, when it leaves the glass, in a path parallel to its path before it entered. But when one or both surfaces are rough, the ray may be directed in any direction (since it can only strike the surface at one point, and a rough surface is composed of particles in different planes), and a beam of light, which is a collection of parallel rays, is scattered. The emerging ray path will not be parallel to the entering path when the surfaces are not parallel, and, by employing various shapes of lenses and prisms, light can be concentrated or spread in any number of ways; some of The Holophane Company's demonstrations of prismatic control are shown on the opposite page. You will notice that in one, a beam of light is totally reflected, demonstrating the existence of a certain critical angle beyond which a ray of light incident on a transmitting medium will not be refracted but reflected. Velocity of light through changing media is a function not only of the indices of refraction of the media, but also of wavelength, and since each wavelength arouses a particular color sensation, the exit path of white light from a refracting material will separate the different colors. This dispersion becomes visible when a prism is used, since the light is refracted twice and the dispersion is greater. The angle of deviation for longer wavelengths is smaller than that for shorter ones, as you see in the center diagram at left, where red light emerges at top, violet at bottom.

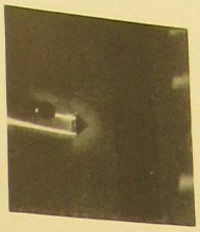
Light, when it hits objects, may also be absorbed in many ratios, which presents no strain on the understanding; transmitted, in many ratios and several styles (sharp, spread, diffuse); and polarized. This last seems to hold greater possibilities for lighting than have yet been realized. In it, all but one of the many planes of oscillation of light waves are eliminated, and glare is reduced enormously; sunglasses use a polarizing material. The bottom diagram at left shows the single plane of oscillation of light after it has passed through a polarizer. Polarization occurs in reflection for certain angles of incidence on a transmitting medium, as well as in refraction.



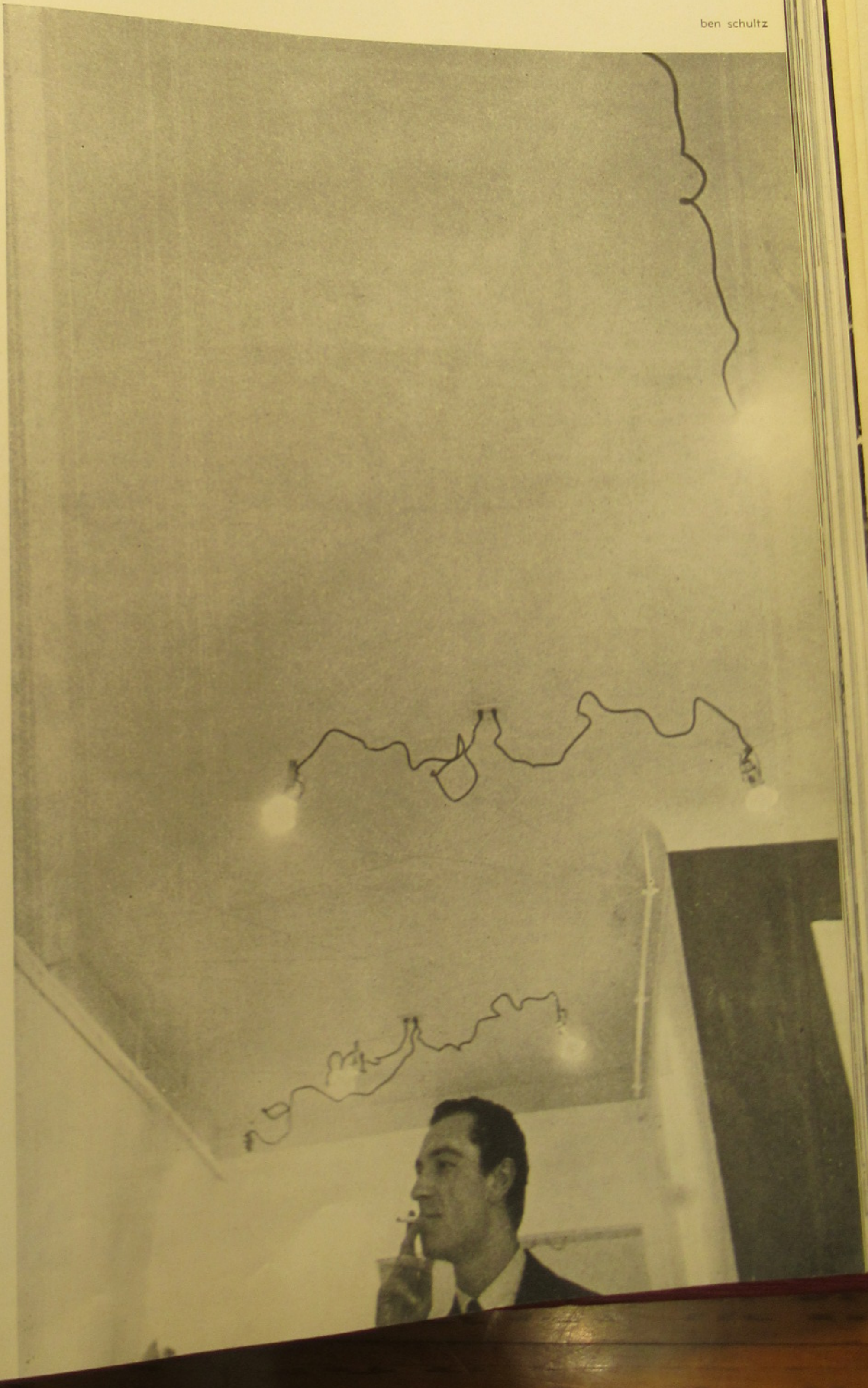
ben schultz

We interrupt instruction and present Roberto Mango beneath sputtering spotlights in the Tibor de Nagy gallery, where designer Mango felt a little excitement was more to the point than a lot of light.



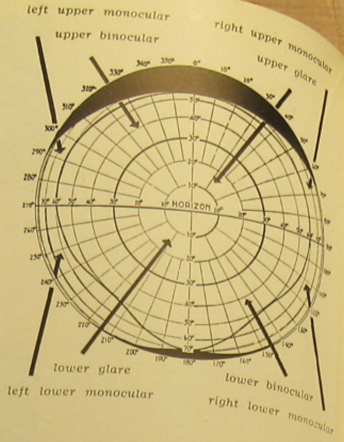


ben schultz



We interrupt instruction and present Roberto Mango beneath sputtering spotlights in the Tibor de Nagy gallery, where designer Mango felt a little excitement was more to the point than a lot of light.

4 The Eye



Lighting is aimed first of all at the eye, without which a concept of light could never have been achieved. The eye's vitally effective parts, those that receive light stimulus, are the sensory elements of the retina, which is a layer of nerve tissues covering the back of the eye. These light receptors are of two types, namely rods and cones, words that describe in general their differences in shape. Cones allow perception of detail and color, and there is a heavy congregation of them at the fovea, located directly back from the opening of the eye. Each cone has its own nerve path to the brain, and that is why recognition of minute detail is possible at the fovea. The rods, 213,000,000 of them, are spread out over the rest of the retina, along with some 10 million cones. Many rods share a single nerve path to the brain, and so allow vague consciousness of things not directly in the line of sight, but cannot see detail, as you can prove by noticing that you can't read any other parts of this paragraph, except perhaps the neighboring one or two lines, while looking at these words. Rods are insensitive to color, too. When the surroundings are at a critical darkness ("critical" here meaning when it is too dark for cones to function), the rods take over the business of seeing, because they are more sensitive to light. When both rods and cones are involved in seeing, as is usual, vision is called *photopic;* when only the rods function, *scotopic.*

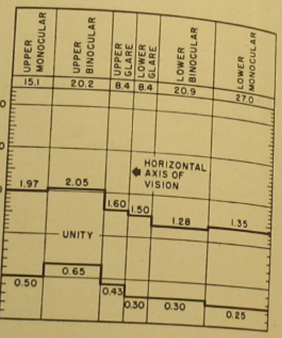
Other parts of the eye are devoted to getting light and transmitting it to the retina and then to the mind. A transparent coating over the lens and pupil, called the cornea, admits light into the eye. The iris lies over the surface of the lens and has a central aperture, the pupil, that adjusts to the amount of light entering and the distance of the things being looked at. The lens, almost always working in synchronization with the pupil, is a focusing agent manipulable in shape by the muscles around it to produce a sharp image on the fovea. At the back of the eye, an optic disc collects light impressions from rods and cones all over the retina and carries them to the brain, where the upside down images are set aright and one is convinced, by nervous and mental processes, that the things he sees are not in his eyes but in corresponding position in space.

The reason the eye should be constantly moving may be merely a matter of getting bored with seeing the same thing from the same position all the time, but the fact is that the eye is much more comfortable, when open, if it moves about. And changes in fixation always take some slight amount of time, involving adaptation of the lens and pupil to the varying brightness, size, and distance of what is being looked at.

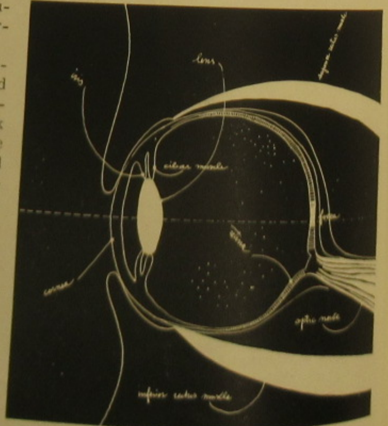
On the whole, the eye is quite well adjusted with the rest of the human personality. It might be wonderful to see all kinds of colors and crisp details in every direction at once if our attention could handle the rush, but since we are such single-minded things, we would only be driven mad, and we gladly settle for the fovea's direct line of sight.

Peripheral vision is certainly not dispensable from any point of view, and particularly not from the designer's, whose compositions would have no more unity or balance than could be achieved by perceiving a series of details. Of course, we consciously (or semi-consciously) examine a thing by a series of perceptions of central vision; our eye falls on an object or scene and we move our foveal vision all over and around: but all the while we are absorbing the relationships of parts in the periphery of vision to the immediate detail in the line of sight, and this synthesis of central and peripheral vision, together with memory of what is not directly in sight at a specific moment, lets us recognize a scene or an object and, if the accumulated senses of relationships and proportions strike us as pleasing, call it good.

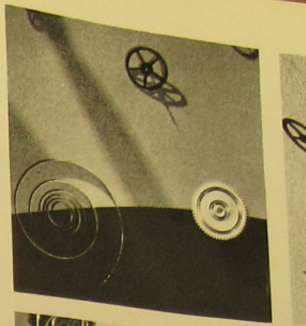
Binocular vision is, as you know, necessary for perception of distance and depth. When one eye is closed, everything looks flat and so close you think you can touch the moon (you must leave off, when performing the experiment, all sophistication about shadows and relative position and known size). Each eye has a slightly different point of view and registers a slightly different image on the retina, and the mind combines both images into one picture that is a mutual modification. This phenomenon, of one eye kind of sneaking behind the edges of what the other eye sees head on, is what makes a ball look round and an interior look as if you can enter it rather than collide with it.

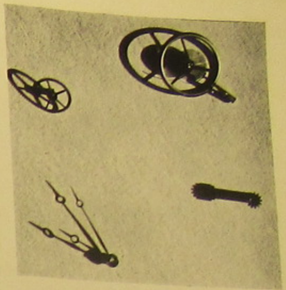


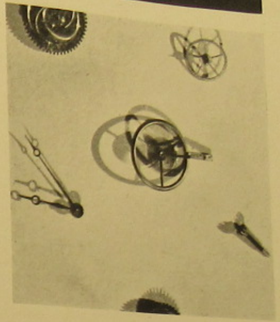
flux analysis chart

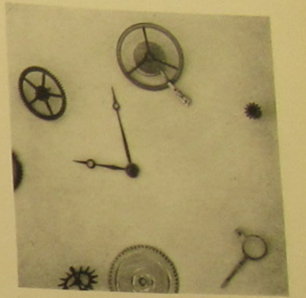


5 Visibility and Comfort









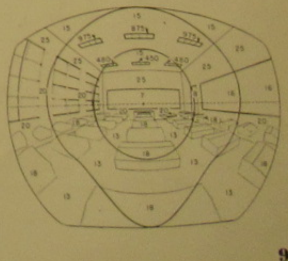
Though we very often focus our eyes on bare space, we usually want to see things truly, and when we are at detail work the business gets complicated. Several factors determine the visibility of an object or detail: its size, its contrast in brightness with the immediate background, the brightness of the whole task, time allowed for seeing, and the brightness relationships between the task and the overall surroundings. Size means visual size, which includes consideration of the object's distance from the eye. The greater the contrast between a detail and its immediate background, the more visible it is; black type is best read on white paper. Color contrasts, even if the colors are of the same brightness, can be almost as effective as brightness contrasts. The brightness of the task is determined by the amount of illumination provided for it, and this is the factor that is most easily controlled; since the others —size, brightness contrast, and, to some extent, the time of viewing are inherent in the task itself. Though there is such a thing as too much illumination—sunlight at high noon is not what you want for reading—an upper limit for most seeing tasks has not yet been found, and ease of vision increases proportionately with increased illumination.

Shadows often contribute, for good or ill, to our perceptions of things. When controlled wisely, they give form and body to an object. One or two concentrated light sources on an object will create deceiving shadows, while diffused light can render the object true, as in the lower right photo above.

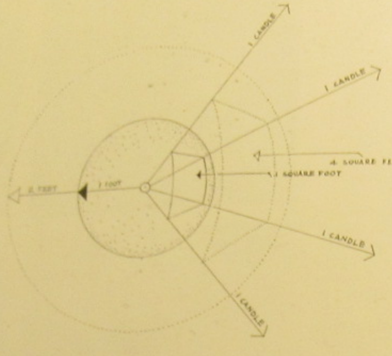
When your eyes are involved in a serious task, you will not be very appreciative of striking contrasts in brightness throughout the room. Not only because the eye automatically raises from the job at times and must take the trouble of adjusting to the brightness of what it looks up to see, but also because peripheral vision is always acting at the same time, though not so intensely or obviously, and the rods happen to like brightnesses similar to those the cones experience when foveal vision is critically used. The Illuminating Engineering Society recommends no more than a five to one brightness relationship between the actual task and the immediate surround; 20 to 1 between the task and more remote surfaces; 40 to 1 between light sources and adjacent surfaces; and 80 to 1 anywhere within the field of vision. These are maximums, and the Society is not really happy with them, preferring much smaller ratios.

Harry L. Logan, now vice president in charge of research at The Holophane Company, has carried his studies of peripheral vision into the realm of anthropology, and has emerged with the judgment that rod vision is one of the reasons man is extant. If we had been equipped with only the sharp line of direct sight, we would all have fallen off cliffs or been victims of other lurking dangers in nature. Today, with automobiles and live wires and all, the dangers are vastly increased, and peripheral vision should be a prime consideration in any lighting job where perils of any sort may lie in wait, such as a bar of soap on the bathroom floor.

Assuming that our eyes have developed by adapting to their natural environment at the time human life took its form, Logan deemed it reasonable to examine light distributions where man assumed his condition. It is known, or practically known, that the only areas where men could live in a natural state, without clothes, fire, or shelter, were a few small areas mostly in Asia Minor, where the temperature always hovered around 70° Fahrenheit. Logan tested the light patterns there on 50 subjects and brought back the Flux Analysis Chart at left. To read it, we must first be familiar with the normal field of view of a pair of human eyes, which explains itself on the opposite page. In the Flux Analysis Chart, the row of figures just below the headings show the percentage of the entire visual field accomplished in each area of vision. If the distribution of light were perfectly even, the factor (the numbers listed on the left side of the chart) for each of these areas would be 1.0. The maximum and minimum relative quantities of light, for each zone, that Logan found at the 70° Isotherm are shown by the two heavy lines crossing the diagrams. The closer you can get to a light distribution that runs down the center of the band, the safer and more cognizant of man's physiology the environment is held to be. The drawing below represents a classroom as it looks from the worst visual position, where a maximum range of contrasts is in view, and shows a distribution of footlamberts that fits within the range recommended in the Flux Analysis Chart.



6 MEASUREMENT



The easiest way to understand the units of light measurement is by using the diagram above, which represents a point source of light in the center of a sphere, of 1 foot radius, that transmits 100% of the light. We will assign the source a luminous intensity of one candle, since *luminous intensity* is the fundamental concept of light measurement, meaning the density of light radiating from a source in a particular solid angular direction. Its unit, the *candle*, is the primary standard of light on which all other standards are based. The value of one candle has been internationally agreed upon, but we won't bother you with an explanation of how much light it is. Mean spherical candlepower is the average candlepower of a source in all directions, and when you talk about candlepower, this is usually what you mean.

One square foot is marked off on the sphere, and the solid angle formed by drawing lines from each of the square's corners to the center of the sphere equals one steradian, a steradian being a solid angle whose sides spread from the center of a sphere in such directions that, at any distance the sphere may be from the source, the portion of the surface marked off by the solid angle will have an area equal to the square of the sphere's radius.

The source emits a constant flow of light, and each wave front has its own period of time; the flow of light per time unit is called *luminous flux*. It is measured in *lumens*, one of which equals the flux emitted through one steradian from a uniform point source of one candle; there is one lumen at the steradian base above. The sphere, with a 1-foot radius, has a total area of 12.57 square feet (4π), and, so, has 12.57 steradian bases. With one lumen per steradian, and the flux going out in all directions, the source is found to deliver a total of 12.57 lumens.

Illumination, measured in *footcandles*, is the density of luminous flux incident on a surface. When one lumen is evenly distributed over one square foot, one footcandle is present at any point on that area, as it is in the drawing above. The number of footcandles is determined by dividing the lumens by the area of the uniformly illuminated surface.

The amount of illumination that seems, to the eye, present at a source or reflected off a surface is *brightness*. Precisely stated, it is the luminous intensity of any surface in a given direction, per unit of the area visible from that direction. One *footlambert*, the unit of brightness, equals 1 lumen per square foot when the lumens are emitted through a perfectly transmitting surface. If a material transmits only a percentage of light, the lumens must be multiplied by that percentage to find the footlamberts. In reflected light, footlamberts are measured by the amount of footcandles (lumens per square foot) divided by the reflectance factor, which is the percentage of incident light that the surface reflects.

As light travels from a source, it spreads out in an ever-increasing span and so becomes less intense. The inverse-square law is an observation that the density of illumination on a surface varies inversely with the square of the distance between the source and the illuminated surface when they are perpendicular to each other. In the diagram above, the illumination at the sphere with a two foot radius is ¼ footcandle since the same amount of flux is spread over an area four times as great as at the inner sphere; at three feet, the illumination would be 1/9 footcandle.

Pocket-size meters have been devised to measure footcandles and footlamberts, which are all that must be worried about finally, since the things they measure are what directly concern your senses.

At right: Lucio Fontana pierces brooding obscurity with spiraling flashes of light.

7

QUALITY AND QUANTITY

The problems of lighting for an interior to work in are usually considered under two headings, quantity and quality. Quantity is fairly uncomplicated, no distinct borderline between enough and too much illumination having yet been found, and there is little danger of getting too much light at a task by artificial lighting. But an increase in footcandle levels will not automatically result in improvement in visibility or comfort. Quality, which includes considerations of brightness ratios, glare, and color, is fussier. The esthetically unwelcome fact that the eyes work most easily if the surrounding brightness levels are fairly even has already been noted. Glare from a light source in the field of view is unthinkable, or should be, and there are several ways of avoiding it or lessening its annoyance. Best of all, of course, is to move the source *out* of the visual field, by raising it higher, imbedding it in the ceiling, or putting it behind louvers. Or the brightness of the source may be reduced by adequate diffusing or shielding; the area of high brightness may be reduced; or the brightness of the areas adjacent to the glare source may be increased.

Reflected glare, caused by high brightness images of light sources reflected from shiny walls, desks, or other surfaces, may be corrected in several ways. Most effective is again to change the position of either the source or the task so that the reflected image will be directed away from the line of vision. The law of reflection being so dependable, it is easy to construct the area from which, were a concentrated light source there, glare would be produced on your task; you simply draw lines from your eyes to the edges of the task (normally extending from points nearly perpendicular to the eyes to points 40° from the vertical) and redirect the lines upward in such a way that the angle of reflectance is the same from a perpendicular line as the angle of incidence, as at right. Lowering the brightness of the source, changing the reflecting surface to a more diffusing one, or increasing the general illumination in the glare area will help reduce the annoyance.

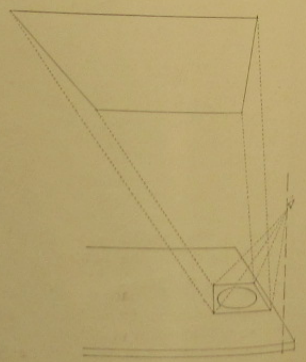
Many illuminating engineers, like Sylvester K. Guth, in charge of lighting research for General Electric, recognize the monotony that can result from equal brightnesses all over the field of vision. Color is the savior. By using different colors of the same, or similar, brightnesses, a work room can take some pleasance without causing physical discomfort. Harry L. Logan and others assume, not unrealistically, that highly chromatic colors are really *too* interesting to be an aid to productivity or safety, and recommend colors of low saturation.

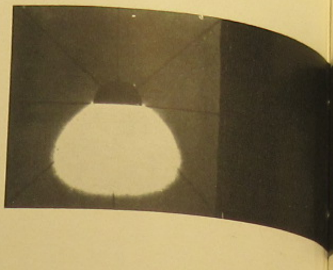
The lighting of an interior usually comprises both general and local lighting. General lighting attempts to distribute flux evenly throughout a room by an arrangement, usually symmetrical, of sources. Local lighting is lighting at or near the place of work, and it is rarely used alone, but to supplement general lighting. Localized general lighting, using light sources mounted above a visual task that contribute to general illumination as well, achieves both immediate and surround light at once.

For any reason at all—economic, functional, esthetic—a certain type of lighting distribution is chosen. *Direct* lighting which sends 90-100% of the light down, gets the highest efficiency, quantity-wise, of all systems, but direct or reflected glare results more easily under this system than any other, and so do great contrasts in brightness. Direct lighting may spread in a broad radius or shoot down sharply. A candlepower distribution curve of downward light is based on the percentage of light emitted that falls within an angle from 0° to 40° of the perpendicular. If only 35-40% of the direct light falls in this area, the distribution is called *broad;* if 60% or more, *focussing,* and there are gradations in between.

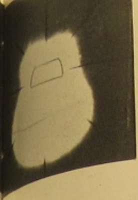
Semi-direct lighting sends 60-90% of the light down, the rest up to illuminate the ceiling and upper walls. Utilization is slightly less than in direct lighting, but brightness ratios and glare are improved. *General diffuse* lighting distributes from 40-60% of the light down and has a strong horizontal component; *direct-indirect* also distributes 40-60% down, but greatly lessens the horizontal part; *semi-indirect* sends 60-90% of the light up, and *indirect,* 90-100% up.

It is obvious that the quantity of light at a work area decreases as the same amount of light gets more indirect, and that the quality of light gets simultaneously better. So every system is bittersweet at best, because it is impossible to get all the lumens of a lamp down on a work surface and so get maximum utilization, and have some lumens left over for general lighting. Undesirable factors in quality in a direct lighting scheme—sharp contrasts, glare—may be controlled by sensible layout and careful choice of equipment. If a room is lighted to a high level by totally indirect lighting, the expense will not be negligible, and a high reflectance factor for the ceiling is vital.

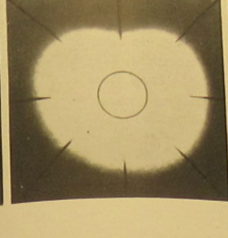




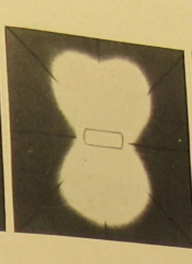
direct



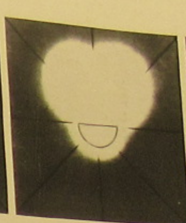
semi-direct



general diffuse



direct-indirect



semi-indirect

indirect

8

THE LUMEN METHOD

Having a room to light for a specific work purpose; accepting the Illuminating Engineering Society's recommended footcandle level for that purpose; assuming that the room's proportions are fixed; settling for the reflectance factors existing, though it is hoped the finishes of walls and ceiling were decided upon with illumination well in mind; and not arguing with the type of light distribution selected—with all these things set, lighting becomes a problem of determining the spacing, number, and candlepower of luminaires necessary to get an even distribution of the desired number of footcandles.

We discuss these things in general terms only, to outline and not exhaust the procedures. Spacing and mounting height of luminaires must be known, at least approximately, before you can calculate the necessary lumens. The distribution curve of the luminaire used and the size and proportions of the room determine to some extent the mounting height, though luminaires are rarely suspended more than four feet from the ceiling. Spacing depends on the type of light distribution and the height of the luminaire; these known, the usual procedure is to estimate a maximum spacing under which the flux delivered from one unit will overlap enough of its neighbors' to attain an even illumination on working surfaces, about 30 inches from the floor. The table on page 146 shows the relationship between distribution curve, mounting height, and maximum spacing.

Achieving the right amount of footcandles has been simplified into formulae by Ward Harrison and E. A. Anderson, both past engineers with General Electric. The working formula is:

$$\text{lamp lumens required} = \frac{\text{footcandles desired x area in square feet}}{\text{coefficient of utilization x maintenance factor}}.$$

A coefficient of utilization, expressed as the percentage of initial lumens that reach a work surface, is necessary because some lumens will be lost due to room proportions and absorption of light both in the luminaire and at various room surfaces. The effect of room proportions on the percentage of light reaching a useful surface under each type of light distribution is accounted for by a Room Index, also formulated by Harrison and Anderson. The Illuminating Engineering Society's *Lighting Handbook* has detailed explanations of the calculations and lengthy, convenient tables showing the room index of any size room. We present a more general table on page 148, and a couple of observations: that large rooms use light more efficiently than small ones with the same height, because there is less proportionate wall area for it to be absorbed at; and that a low ceiling preserves more lumens than a high one in a room of the same size otherwise, for the same reason.

The table on page 150 has coefficients of utilization computed for six types of distribution, and you will notice that flux distribution curves and reflectance factors are as important as room index in determining the coefficient. Manufacturers will tell you how much absorption of light you can expect in the luminaire itself.

Since the efficiency of a light source is reduced after it has been working for a little time, a maintenance factor must also be taken into account. Incandescent lamps average, over a period of time, about 85-90% of the original lumen output; fluorescent, around 80-85%.

Putting the significant values — footcandles desired, area in square feet, coefficient of utilization, and maintenance factor—into the formula, you get the total number of lumens needed; and, having a general idea of the spacing and, so, the number of luminaires, you divide the lumens among them, modifying the number of luminaires or the lumens provided by each if sense so decrees.

The demands on an interior usually transcend physiological comfort, however, and most designers feel that relegating lighting to science robs them of one of their most flexible and effective design materials. Variations in composition and, concomitantly, in mood possible under different treatments of lighting only begin to suggest themselves in the four ceilings here. The one the girl points at is composed of Panelescent, a luminous panel whose developers, Sylvania Electric, hope can at last become an area light source and be incorporated into the very structure of a building. At a high intensity of white light (not feasible yet), Panelescent would provide cool, detached, almost shadowless illumination. Glowing under lower intensity (as it can now), and in a choice of colors, it might offer a pleasing, relaxed surrounding after the excitement of novelty wears off, accepted as a coat of glowing paint that incidentally provides some general illumination.

Inventor R. Gillespie Williams' "Rollo-Color" ceiling, a huge honeycomb, filled with colored lights, swooping down on a Madison Avenue office lobby, validates its schmaltzy existence by being such jolly good fun. Both Panelescent and Rollo-Color will appear again in our next month's installment, as new techniques that may hold lurking advantages for designers.

Contrast with the honeycomb the grand stateliness of Sven Markelius' Economic and Social Chamber at the United Nations building, top right, where huge round coves are punctuated with small spotlights, making an extremely formal design. Finn Juhl's "flying fences" at the UN's Trusteeship Council Chamber are brightly colored and exuberant without the slightest loss of dignity, though pomp is gone forever.

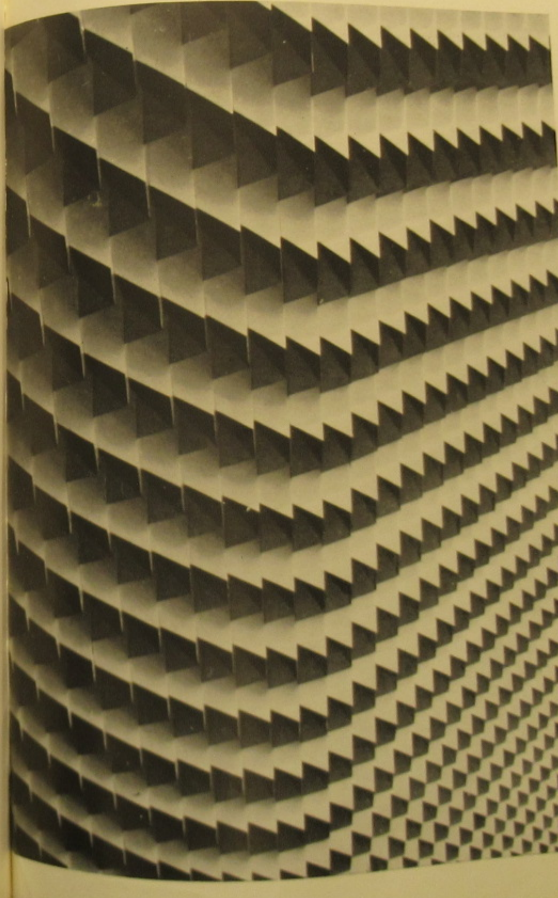
But what light comes from, and even the design treatment of the sources, is much less important architecturally than light itself. Richard Neutra puts the idea succinctly, and broadly: "Space is mostly illuminated space." You see what he means in the photograph of the desert house on page 107, where even the mountains, depth after depth of illuminated spaces, contribute to the demonstration; were they unilluminated, and thus invisible, the subtleties of space gradation would not exist, so far as we could care. Space as such is not visible, of course, but only the materials and surfaces that enclose, define, or suggest a space. Those materials only being visible when light is reflected off them, the experiencing of any space becomes dependent not only on the character and design of the materials, but on the character of the light they are seen by as well. Light as such, i.e., as energy, is never seen, either, and makes its presence known only at its bodily source or when it is reflected off a physical thing, be it a mere dust particle. So light can do nothing by itself for a design, but must be considered with respect to the surfaces it shines on.

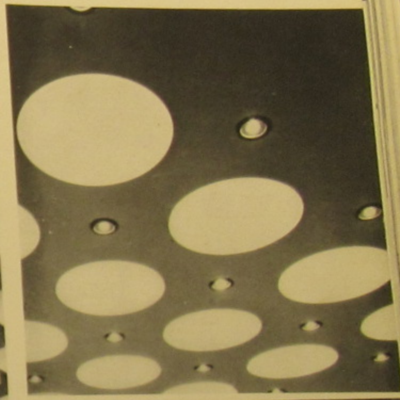
On the following pages, instances appear in which lighting has been used in rather prepossessing ways to make something coherent and pleasing of a space, always in association with the materials in that space, however subtly the materials and lighting may be employed, to suggest an openness, an interplay, or an interpenetration of spaces within a larger comprehension, as well as blunt enclosures. Projecting yourself into each interior, you will usually find an atmosphere of some sort, an accumulated effect that arouses a rather specific emotional response relating that interior to yourself. If you pay particular attention to the lighting, you will see that it is a major evocative factor, drawing much of its inspiration from the stage, where the establishment of a mood, a psychological preparation, is lighting's first concern.

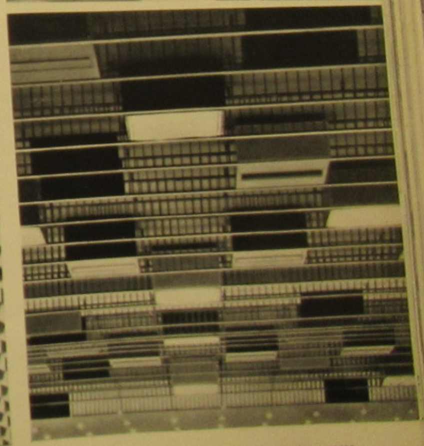
In Buenos Aires' Gran Rex Theater (page 108), architects Catalano, Nery, Grego, Degiorgi, Gonzáles Gandolfi, and Lanús use light as a major architectural material. The bold shell, composed of vaulting ceiling panels irrepressibly closing in on the stage, is brought to important visual reality by fluorescent strips behind the panels, always drawing the attention to the proscenium even while you are merely enjoying the architecture.

Examining the other theaters shown, you see the differences in feeling created by the relationships between light and the forms in space. Those on the left are broadcasting studios, and the unusual shapes are present essentially for acoustical purposes, but become dominant visually when light falls on them. Top is a detail of an NBC studio by Carson & Lundin, where the domes break up the sound and prevent bothersome echoes by keeping the walls unparallel, while perforated transite absorbs unwanted noise. The ceiling is deeply zigzagged over the entire studio, and fluorescent tubes stretch in the grooves from wall to wall, kept out of the line of vision by the pitch of the ridges. To eliminate the usual hum from fluorescent lighting, quite inimical to microphones, all the ballasts, which cause the hum (and determine the amount of

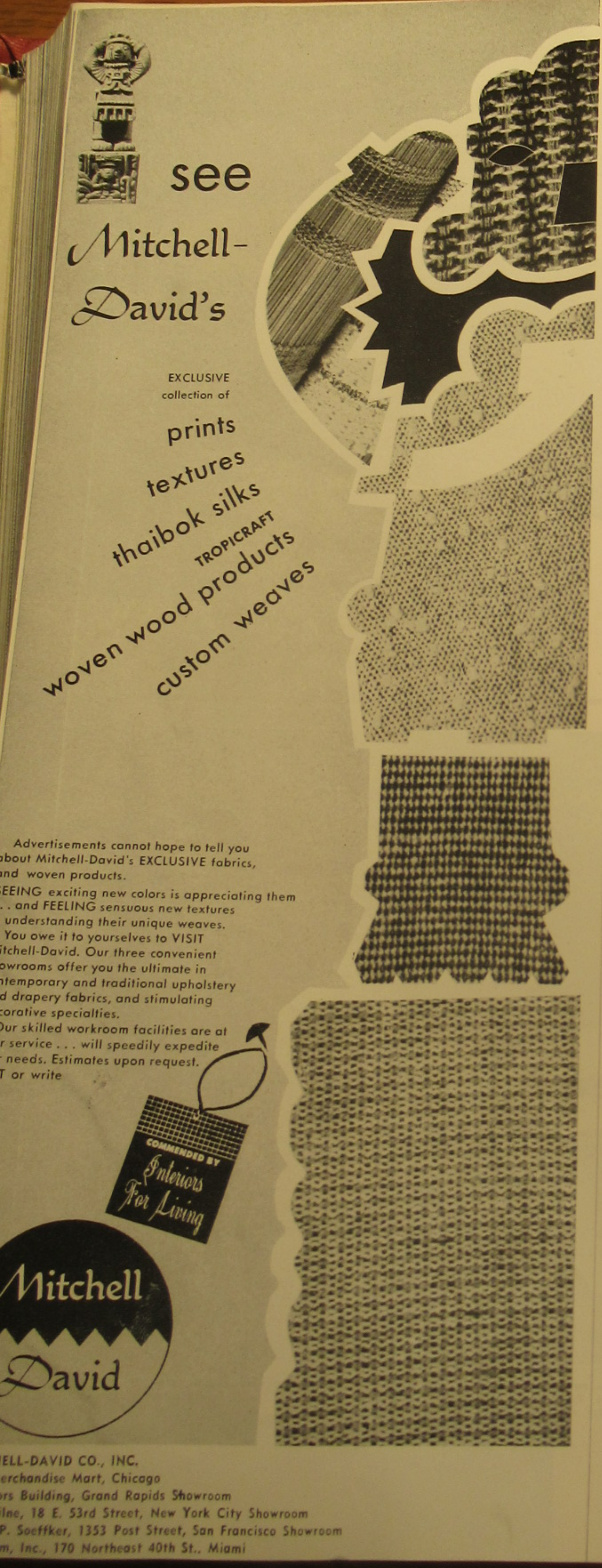
(Continued on Page 150)







both photographs above right: alexandre georges



Lighting in Design

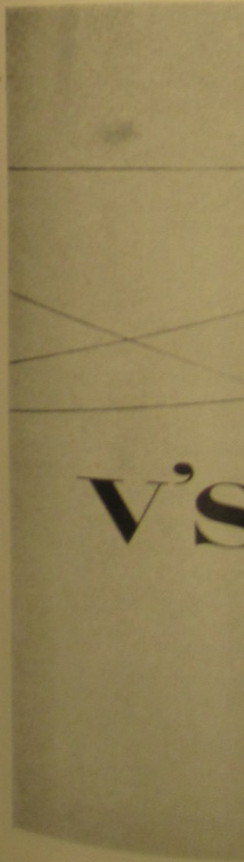
(Continued from page 104)

current) were assembled in a box in the studio rear. In the bottom photo, a German association of architects, the *Arbeitsgemeinschaft der Architekten*, create a mysterious, rather foreboding play of forms cut out behind gaboon staves, made even more nebulous and musical by lights behind the waving cutouts, hinting at reaches of space back there, while the staves softly filter the light into the room. The Nuremberg theater at bottom, by German architect Paul Bode, is impressive in scale and in the high, astute floodlights tapering down the wave-like draperies, but the fabric is golden yellow, and there are hundreds of tiny spotlights sprinkled over the ceiling to temper the austerity. In the desert house, Richard Neutra focuses and separates areas with telling pools of light but keeps the space a coherent unit with fluorescent tubes taking the measure of the structure, emphasizing its horizontality, and by putting lights in the pool as well as on the interiors to draw outdoors into the sensible environment.

A comparison of the spotlights and floodlights Neutra uses here with the valance fluorescent lighting in the view we show of the house Marcel Breuer designed at the Museum of Modern Art reveals the difference in character between the two major kinds of light sources today. Fluorescence affords little concept of depth and texture, and drama, significance, or charm are easily absent; but it can achieve a relaxing calmness. Incandescence can be charged with punch and excitement, can create impressive shadows, bring a texture to life. Fluorescence diffuses light unselectively over a relatively large area, and can easily unify a space, often in a flat and naive way (witness so many restaurants and stores); while incandescence, more strongly directional, can break up a space into a pattern, emphasize areas of interest, and is almost indispensable in establishing a strong focal point in a design. Spotlights and floodlights dramatize two vastly different textures, blue silk curtains in an apartment by lighting expert Richard Kelly at top of page 106, and a two-story brick fireplace wall in a house by Henry Hebbeln and William Diederich, for which Mr. Kelly was lighting consultant, on page 107. In each case, the wall area lighting, besides being engaging to the eye, affords general illumination, what Mr. Kelly calls "ambient luminescence," for the room. This soft, reassuring surround is focalized by bright areas of more attractive specular light.

You will notice portable lamps in these interiors, contradicting the advancing esthetic of built-in lighting; Mr. Kelly feels that the main lighting for design ought to be accomplished by architectural lighting, all right, but that a few portables should remain so that people won't feel dictated to by light but can shift it around to suit their fancies. While not quite sheer romance to Marcel Breuer, who admits to liking an occasional goose-neck, this attitude was not in evidence in Breuer's Modern Museum house, where he did without portables of any kind, for several avowed or implied reasons: to use light clearly as an element of architecture, in which the source of light is a little irrelevant and might better not call attention to itself; and that he would rather not have sculptures foisted on him along with lighting equipment.

Whether their chief significance is as sculpture rather than lighting, decorative fixtures *can* be quite effective in setting the mood of an interior, and if they employ their bodily selves in strict visual relation with the light they deliver, they can be more than corporeal ornament but afford an agreeable light sensation as well. See the evocative shadows floating on the ceiling of the Virgin Isles Hotel ballroom (page 111) by architect Harold Sterner,



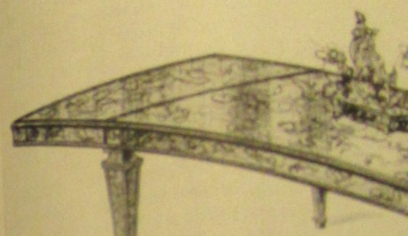
created by Richard Kelly's bent wire chandeliers. Alexander Calder's brightly colored, plant-filled pots (page 109) for the stairwell of Edward Stone's projected San Salvador Hotel are wonderfully festive, each containing a light bulb to throw light up into the plants. Besides, there are tiny punctures in the pots, offering pinpoints of light downward, and many small spotlights clustered in the ceiling to sprinkle light on the greenery. The drawing shows the pots in position, and you can imagine the delight of ascending the stairs and passing the exhilarating articulation of form, color, and light. When you reach the dining room, Japanese lanterns continue the pleasantries with their own particular charm.

The color of anything is determined as much by the light it is seen by as anything else, and there is nothing technological to prevent you from "painting a room with light," as the saying goes in lighting circles. If you have a room with white walls, and keep too much daylight from coming in, you can effect basic changes in design and mood with glass or gelatine color clips on the light sources. Much of the light will be lost, naturally, and other considerations must outweigh pragmatic service. Colors can mold a space, not only in their surface adjacence or relative position, separating elements, but in the depth perceptions they effect on the eye. Some colors are easier to focus—red, orange, especially yellow—than others—green, blue, purple—and so the former make a space or an object a sharply defined thing, while the latter are a little more indistinguishable and wavering in space. While darker colors ordinarily crowd upon you, comfortingly or claustrophobically, depending on your disposition, and lighter colors seem farther away, an area or surface in relative shadow appears farther and more suggestive than a brightly lit surface of the same color. The color of a surface will have some gradations and appear more saturated, but less bright, when white light glances off it diagonally than when the surface is perpendicular to the light source.

Fashion window displays have a lesson to impart concerning the rendition of complexion. Bluish lights in the background and, slightly, on one side of the face, and pink lights mostly on the face make the models look pink and pretty, by sensibly employing the eye's exaggeration of adjacent color differences.

Unlike constantly changing daylight, nearly all lighting practice today offers a stable picture of what it illuminates. Mobile light has been urged for wider applications for several years, by, among others, Gyorgy Kepes of the School of Architecture and Planning at Massachusetts Institute of Technology, who has experimented at length with light and lighting, and Stanley McCandless, professor of lighting at Yale University and consultant to Century Lighting, who has done much work with the stage. Moving a flashlight through a darkened room, you see, in an extreme form, what mobile light can do to an interior, making things leap out at you in sudden life and just as suddenly fall into oblivion, sending shadows traveling across the forms, and it looks, really, though you are so sophisticated as to know better, as if the room itself is moving. You may not want such pulsation very often, but gradual movements and changes in the intensity and color of light occur under natural illumination all the time, and, human eyes having developed without the aid of filament, it seems reasonable to expect slow, not quite insensible, modulations of light to be agreeable. Gyorgy Kepes holds that the sense of motion or change is "as fundamental a human need as the need for a sense of the broadest possible space. Motion frees the existence in time in the same way that openness frees the perception of space."

While special installations must be rigged up to achieve mobile light, less complicated equipment is available to



change the color and intensity of light. Dimmers can be operated from chairside. Luxor Lighting has assembled "Rollo-Color" into a portable package, running on a motor to create an ever-changing environment till you stop the motor, but the changes are usually not slow enough to be exactly what you want. Special custom jobs may be done to specifications, however.

Movement can be implied in an actually stable use of light, as in the Merchandise Mart's Good Design show by Paul Rudolph. Were you where the camera is in the photograph on page 109, which is only one of many viewpoints, you would find a bright path pulling you along, past a relatively dark area, to a vibrating field of interwoven light and dark. Walking through here, your own shadow becomes a major part of the experience, lengthening and disappearing to arouse a sense of your immediate association with the space. Spotlights way back beyond the screen make you aware of more areas, tying them in with the others and maintaining a carefully modulated flow. Richard Kelly was again the lighting consultant.

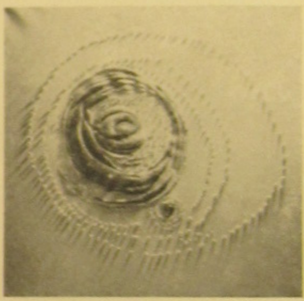
The Peacock Lounge of Warner-Leeds Caribe Hilton (page 111), a broad and spacious hall, is molded by Gotham Lighting Company's indirect domes hung at various levels to reenforce light in spots, dwindle it in other places, all very softly and gradually, to keep the room a unified, but unmonotonous, whole.

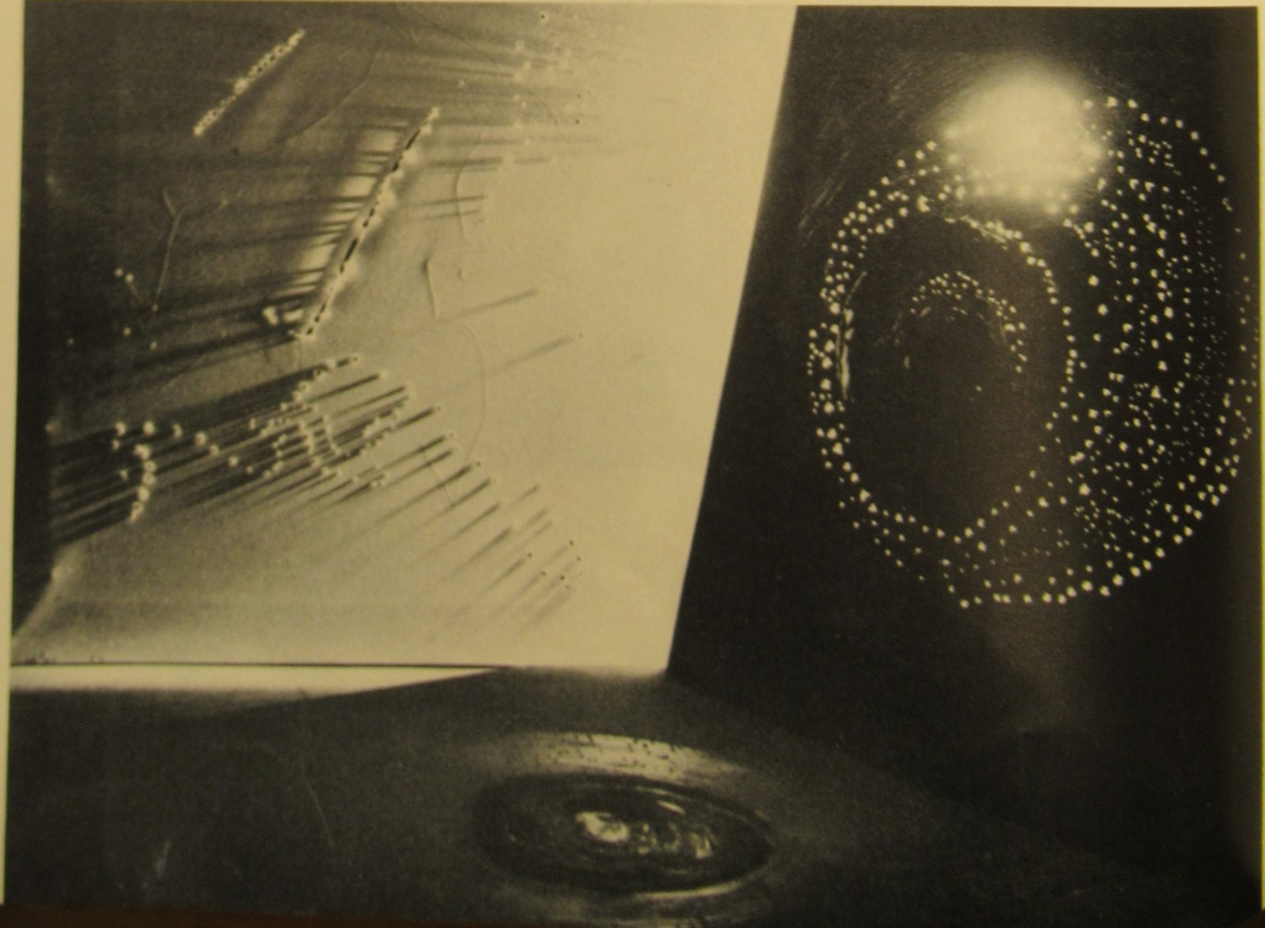
On page 110, two offices are provided with excellent illumination, and, in both, the ceilings are made into architectural elements of light in different degrees of importance. Richard Neutra diminishes the visual weight of an egg-crate ceiling, and even gives it a kind of elegance, in Los Angeles' Northwestern Mutual Fire Association building by pushing it above the regular ceiling level and providing handsome materials for it to work in association with. The bottom photo, of the J. Walter Thompson advertising agency in New York, shows only a small part of a vast office area entirely covered with an immensity of light behind orderly, diffusing glass panels.

To close the first installment of a two-part article on lighting, we present Lucio Fontana's "spatial conceptions" on pages 112 and 113. Sr. Fontana uses them "in place of paintings or sculptures," he says, but of course they *are* sculptures. Never more clearly has the interdependence of light and the forms in space been demonstrated, and with the most limited of elements—sheets of metal, grains of crystal, a light bulb. The forms determine the visual character of the light, and at the same time the light determines the appearance of the forms; whichever viewpoint you take, though they should be taken at the same time, something is done to your perception of space. In the large photo on page 113, light is directed along the surface of a sheet of metal, almost parallel with it, catching the jagged punctures and casting long, intermelting shadows that fan just perceptibly outward in a span that continually widens till it spills off the finite page. Just below that are winding strings of punctured holes, much the same physically but little like in aspect when the source of light is moved from the front to the rear, turning what had been a textured surface into a blackness dotted with light. On the opposite page, in the large photo, you see three more spatial suggestions, all evoked from a single light source directed on three carefully positioned sheets. A spiral of light seems to come from nowhere, and a sudden flash bursts through where the bulb is directly behind the sheet. A ghostly whirlpool shimmers where diffuse light glances off at a sharp angle, coming through the spiral and from reflections off the white sheet. Bumps on the white sheet stretch shadows along the lightly grained surface, giving the bumps an importance not inherent in them, seeming to bend the sheet where the shadows multiply, hinting at the dimensional moldability of space as space makes itself known to the eye.

LUCIO
FONTANA

publifoto





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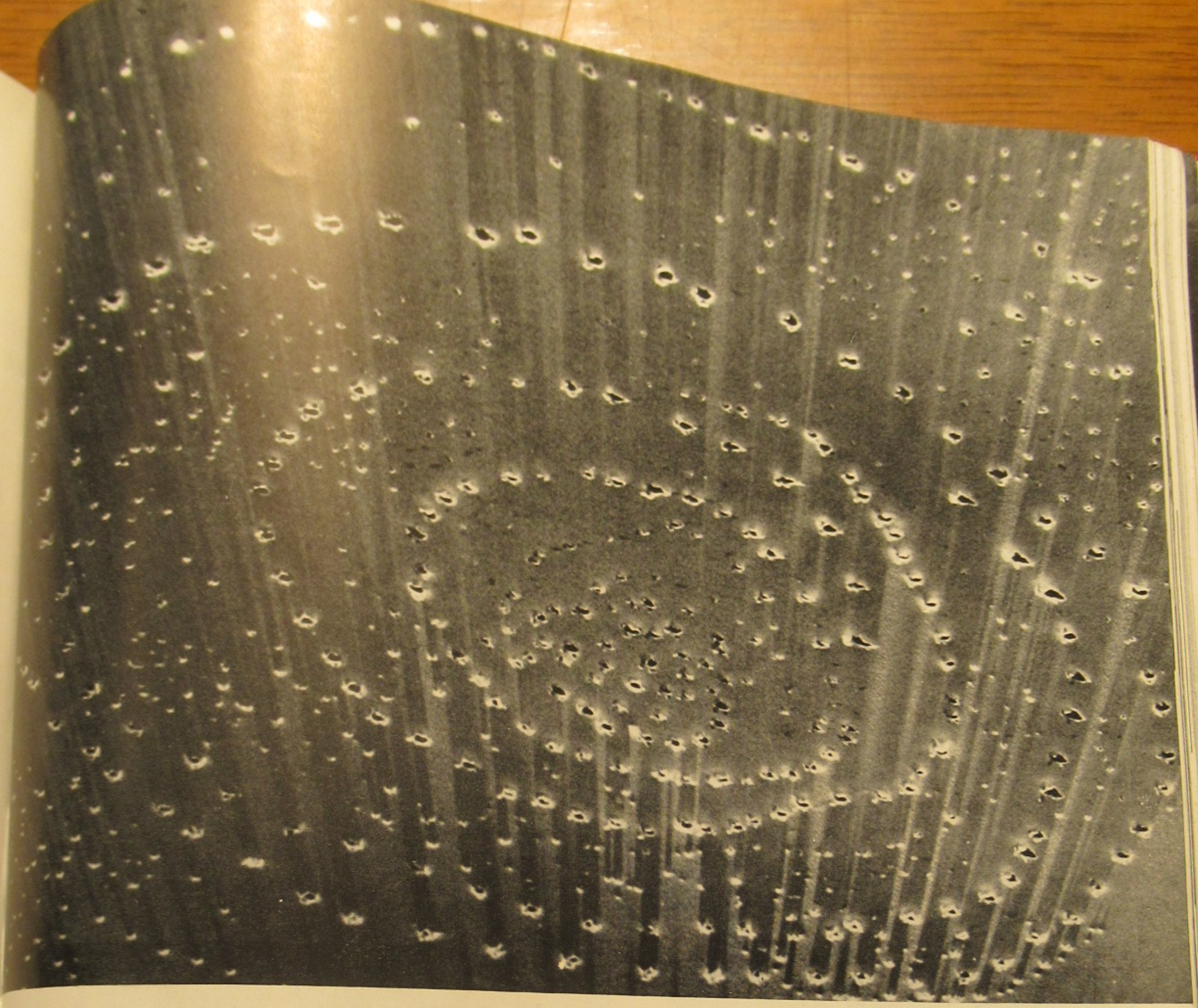

cesare mancini

Lucio Fontana, Milanese sculptor-ceramist, demonstrates in many ways on these pages his approach to light as an art form. Holes punched through sheets of metal are not only holes, but, on the other side of the sheet, raised frames of holes, and either way they are wonderful when light is cast on them, from behind to present a spectacle of stars as in a vast sky, from in front to create a texture of winding bends, from the side to lengthen shadows as on a desert near sundown. Or swirling tubes, like those adorning the Triennale of Milan (September 1951 Interiors) or that beneath which Sr. Fontana sits, opposite, make you aware of more than the plasticity of the tube, that of light itself as well.