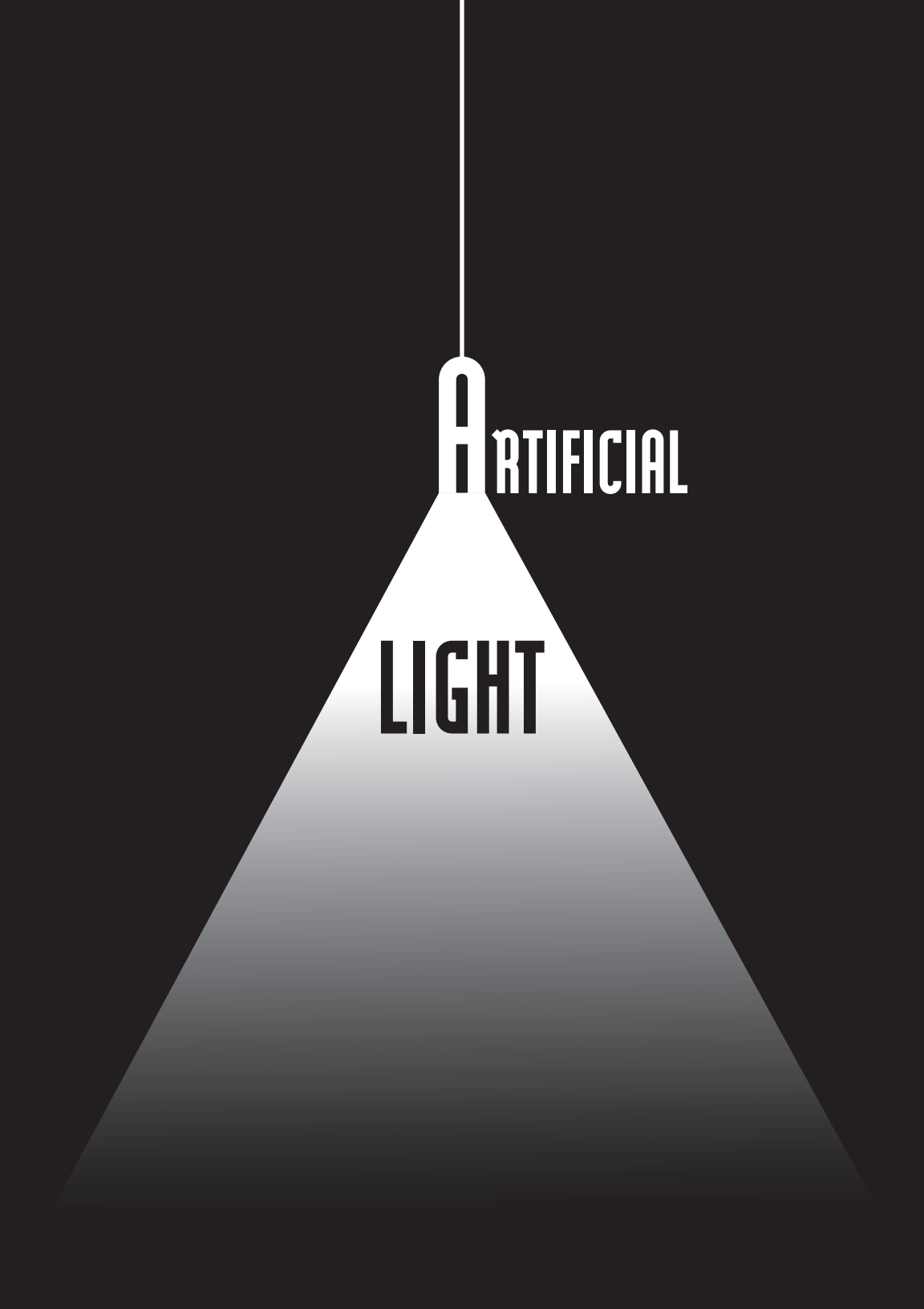
ARTIFICIAL
LIGHT

ARTIFICIAL LIGHT

Excerpt From

Artificial Light: Its Influence upon Civilization

By Matthew Luckiesh

SARAH NA

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01 LIGHT AND HUMAN

The human race was born in slavery, totally subservient to nature. The earliest primitive beings feasted or starved according to nature's bounty and sweltered or shivered according to the weather. When night fell they sought shelter with animal instinct, for not only were activities almost completely curtailed by darkness but beyond its screen lurked many dangers. It is interesting to philosophize upon a distinction between a human being and the animal just below him in the scale, but it may serve the present purpose to distinguish the human being as that animal in whom there is an unquenchable and insatiable desire for independence. The effort to escape from the bondage of nature is not solely a human instinct; animals burrow or build retreats through the instinct of self-preservation. But this instinct in animals is soon satisfied, whereas in human beings it has been leading ever onward toward complete emancipation.

THE HUMAN RACE WAS BORN IN SLAVERY

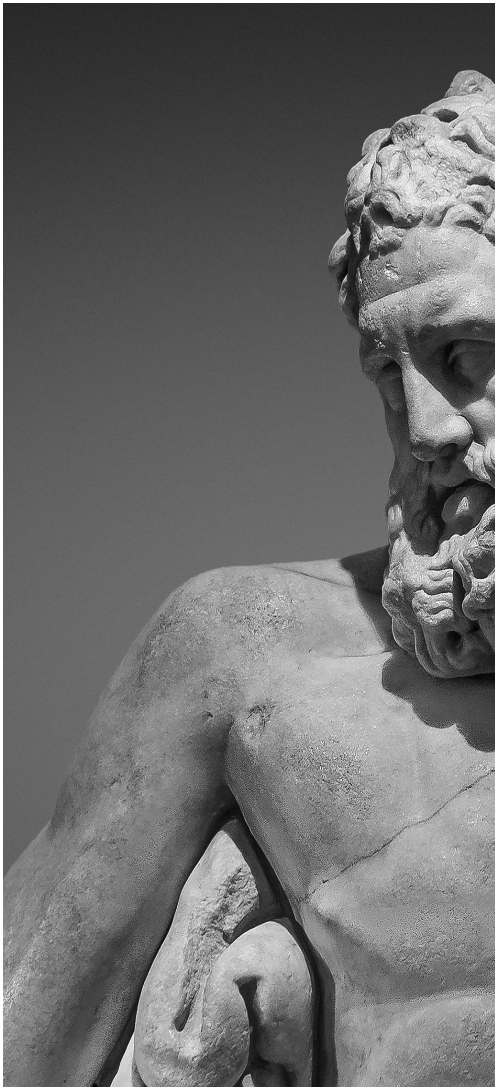
THE BEGINNING

The progress of civilization is a long chain of countless achievements each one of which has increased man's independence. Early man perhaps did not conceive the idea of fire and then set out to produce it. His infant mind did not operate in this manner. But when he accidentally struck a spark, produced fire by friction, or discovered it in some other manner, he saw its possibility. It is thrilling to picture primitive man at his first bonfire, enjoying the warmth, or at least interested in it. But how wonderful it must have become as twilight's curtain was drawn across the heavens! This controllable fire emitted light. It is easy to imagine primitive man pondering over this phenomenon with his sluggish mind.

Doubtless he cautiously picked up a flaming stick and timidly explored the crowding darkness. Perhaps he carried it into his cave and behold! Night had retreated from his abode! No longer was it necessary for him to retire to his bed of leaves when daylight failed. The fire not only banished the chill of night but was a power over darkness. Viewed from the standpoint of civilization, its discovery was one of the greatest strides along the highway of human progress. The activities of man were no longer bounded by sunrise and sunset. The march of civilization had begun.

In the present age of abundant artificial light, with its manifold light-sources and ac-

cessories which have made possible countless applications of light, mankind does not realize the importance of this comfort. Its wonderful convenience and omnipresence have resulted in indifference toward it by mankind in general, notwithstanding the fact that it is essential to man's most important and educative sense. By extinguishing the light and pondering upon his helplessness in the resulting darkness, man may gain an idea of its overwhelming importance. Those unfortunate persons who suffer the terrible calamity of blindness after years of dependence upon sight will testify in heartrending terms to the importance of light. Milton, whose eyesight had failed, laments,



O FIRST CREATED BEAM AND THOU GREAT WORD,
"LET THERE BE LIGHT,"
AND LIGHT WAS OVER ALL,
WHY AM I THUS BEREAVED THY PRIME DECREE?

Perhaps only through a similar loss would one fully appreciate the tremendous importance of light to him, but imagination should be capable of convincing him that it is one of the most essential and pleasure-giving phenomena known to mankind.

A retrospective view down the vista of centuries reveals by contrast the complexity with which artificial light is woven into human activities of the present time. Written history fails long before the primitive races are reached, but it is safe to trust the imagination to penetrate the fog of unwritten history and find early man huddled in his cave as daylight wanes. Impelled by the restless spirit of progress, this primitive being grasped the opportunity which fire afforded to extend his activities beyond the boundaries of daylight. The crude art upon the walls of his cave was executed by the flame of a smoking fagot. The fire on the ledge at the entrance to his abode became a symbol of home, as the fire on

the hearth has symbolized home and hospitality throughout succeeding ages. The accompanying light and the protection from cold combined to establish the home circle. The ties of mated animals expanded through these influences to the bonds of family. Thus light was woven early into family life and has been throughout the ages a moralizing and civilizing influence. Today the residence functions as a home mainly under artificial light, for owing to the conditions of living and working, the family group gathers chiefly after daylight has failed.

From the pine knot of primitive man to the wonderfully convenient light-sources of to-day there is a great interval, consisting, as appears retrospectively, of small and simple steps long periods apart. Measured by present standards and achievements, development was slow at first and modern man may be inclined to impatience as he views the history of light and human progress. But the achievements of early centuries, which appear so simple at the present time, were really great accomplishments when considered in the light of the knowledge of those remote periods. Science as it exists today is founded upon proved facts. The scientist, equipped with a knowledge of physical and chemical laws, is led by his imagination into the darkness of the unexplored unknown. This knowledge illuminates the pathway so that hypotheses are intelligently formed.

These evolve into theories which are gradually altered to fit the accumulating facts, for along the battle area of progress there are innumerable scouting-parties gaining secrets from nature. These are supported by individuals and by groups, who verify, amplify, and organize the facts, and they in turn are followed by inventors

who apply them. Liaison is maintained at all points, but the attack varies from time to time. It may be intense at certain places and other sectors may be quiet for a time. There are occasional reverses, but the whole line in general progresses. Each year witnesses the acquirement of new territory. It is seen that through the centuries there is an ever-growing momentum as knowledge, efficiency, and organization increase the strength of this invading army of scientists and inventors.

THE BURNING BRANCHES RESCUED MANKIND FROM THE SHACKLES OF DARKNESS, AND THE GREASE-LAMP AND TALLOW-CANDLE HAVE DONE THEIR PART. Progress was slow in those early centuries because the great minds of those ages philosophized without a basis of established facts: scientific progress resulted more from an accumulation of accidental discoveries than by a directed attack of philosophy supported by the facts established by experiment. It was not until comparatively recent times, at most three centuries ago, that the great intellects turned to systematically organized scientific research.

Such men as Newton laid the foundation for the tremendous strides of today. The store of facts increased and as the attitude changed from philosophizing to investigating, the organized knowledge grew apace. All of this paved the way for the momentous successes of the present time.

02 ARTIFICIAL LIGHT

The end is not in sight and perhaps never will be. The unexplored region extends to infinity and, judged by the past, the momentum of discovery will continue to increase for ages to come, unless the human race decays through the comfort and ease gained from utilizing the magic secrets which are constantly being wrested from nature. Among the achievements of science and invention, the production and application of artificial light ranks high. As an influence upon civilization, no single achievement surpasses it. Without artificial light, mankind would be comparatively inactive about one half its lifetime. Today it has been fairly well established that the human organism can flourish on eight hours' sleep in a period of twenty-four hours. Another eight hours spent in work should settle man's obligation to the world. The remaining hours should be his own. Artificial light has made such a distribution of time possible. The working-periods in many cases may be arranged in the interests of economy, which often means continuous operations. The sun need not be considered when these operations are confined to interiors or localized outdoors.

THE END IS NOT IN SIGHT AND

LIGHT AND LIFE

Artificial light has been an important factor in the great industrial development of the present time. Man now burrows into the earth, navigates under water, travels upon the surface of land and sea, and soars among the clouds piloted by light of his own making. Progress does not halt at sunset but continues twenty-four hours each day. Building, printing, manufacturing, commerce, and other activities are prosecuted continuously, the working-shifts changing at certain periods regardless of the rising or setting sun. Adequate artificial lighting decreases spoilage, increases production, and is a powerful factor in the prevention of industrial accidents.

It has ever been true since the advent of artificial light that the intellect has been largely nourished after the completion of the day's work. The highly developed artificial lighting of the present time may account for much of the vast industry of publication. Books, magazines, and newspapers owe much to convenient and inexpensive artificial light, for without it fewer hours would be available for recreation and advancement through reading. Schools, libraries, and art museums may be attended at night for the betterment of the human race. The immortal Lincoln, it is said, gained his early education largely by the light of the fireplace. But all were not endowed with the persistence of Lincoln,

so that illiteracy was more common in his day than in the present age of adequate illumination.

The theatrical stage not only depends for its effectiveness upon artificial light but owes its existence and development largely to this agency. In the moving-picture theater, pictures are projected upon the screen by means of it and even the production of the pictures is independent of daylight. These and a vast number of recreational activities owe much, and in some cases their existence, to artificial light.

Not many centuries ago the streets at night were overrun by thieves and to venture outdoors after dark was to court robbery and even bodily harm. In these days of comparative safety it is difficult to realize the influence that abundant illumination has had in increasing the safety of life and property. Maeterlinck in his poetical drama, "The Bluebird," appropriately has made Light the faithful companion of mankind. The Palace of Night, into which Light is not permitted to enter, is the abode of many evils. Thus the poet has played upon the primitive instincts of the impressiveness of light and darkness.

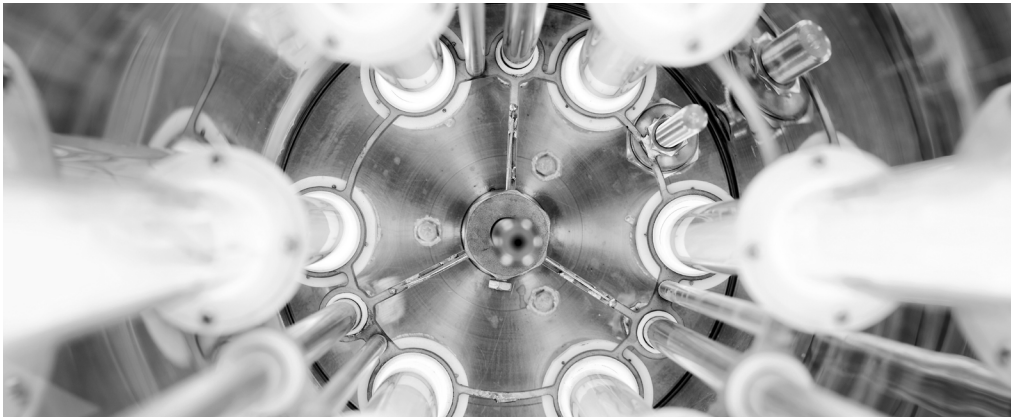
By combining the symbolism of light, color, and darkness with the instincts which have been inherited by mankind from its superstitious ancestry of the age of mythology, another field of application of artificial light is opened. Light has gradually assumed such attributes as truth, knowledge, progress, enlightenment. Throughout the early ages light was more

or less worshiped and thus artificial lights became woven in many religious ceremonies. Some of these have persisted to the present time. The great pageants of peace celebrations and world's expositions appropriately feature artificial light. In drawing upon the potentiality of the expressiveness and impressiveness of light and color, artificial light is playing a major part. Doubtless the future generations will be entertained by gorgeous symphonies of light. Experiments are performed in this direction now and then, and it is reasonable to expect that after many centuries of cultivation of the appreciation of light-symphonies, these will take a place among the arts. The elaborate and complicated music of the present time is appreciated by civilized nations only after many centuries of slow cultivation of taste and understanding.

Light-therapy is to-day a distinct science and art. The germicidal action of light-rays and of some of the invisible rays which ordinarily accompany the luminous rays is well proved. Wounds are treated effectively and water is sterilized by the ultraviolet radiant energy in modern artificial illuminants.

Thousands of lighthouses, light-ships, and light-buoys are scattered along seacoasts, rivers, and channels. They guide the wheelman and warn the lookout of shoals and reefs. Some of these send forth flashes of light whose intensities are measured in millions of candle-power. Many are unattended for days and even months. These powerful lights dominated by automatic mechanisms have replaced the wood-fires which were maintained a few centuries ago upon certain prominent points.

SIGNAL-LIGHTS NOW GUIDE THE RAILROAD TRAIN THROUGH THE NIGHT. A burning flare dropped from the rear of a train keeps the following train at a safe distance. Huge search-lights penetrate the night air for many miles. When these are equipped with shutters, a code may be flashed from one ship to



another or between the vessel and land. A code from a powerful search-light has been read a hundred miles away because the flashes were projected upon a layer of high clouds and were thus visible far beyond the horizon.

Artificial light played its part in the recent war. Huge search-light equipments were devised for portability. This mobile apparatus was utilized against enemy aircraft and in various other ways. Small hand-lamps are used to send out a pencil of light as directed by a pair of sights and the code is flashed by means of a trigger. Raiding-parties are no longer concealed by the curtain of darkness, for rockets and star-shells are used to illuminate large areas. Flares sent upward to drift slowly downward supported by parachutes saved and cost many lives during the recent war. Rockets are used by ships in distress and also by beleaguered troops.

Experiments are being prosecuted to ascertain the possibilities of artificial light in the forcing of plant-growth, and even chickens are made to work longer hours by its use.

Artificial light is now modified in color or spectral character to meet many requirements. Daylight has been reproduced in spectral quality so that certain processes requiring accurate discrimination of color are now prosecuted twenty-four hours a day under artificial daylight. Colored light is made of the correct quality which does not affect photographic plates of various sensibilities. Monochromatic light is utilized in photo-micrography for the best rendition

of detail. Light-waves have been utilized as standards of length because they are invariable and fundamental. Numerous other interesting adaptations of artificial light are in daily use.

This is in reality the age of artificial light, for mankind has not only become independent of daylight in certain respects, but has improved upon natural light. The controllability of artificial light makes it superior to natural light in many ways.

In fact, uses have been made of artificial light which are impossible with natural light. Light-sources may be made of a vast variety of shapes, and those may be transported wherever desired. They may be equipped with reflectors and other optical devices to direct or to diffuse the light as required.Thus, artificial light today has numerous advantages over light which has been furnished by the Creator. It is sometimes stated that it can never compete with daylight in cheapness, inasmuch as the latter costs nothing. But this is not true. Even in the residence, daylight costs something, because windows are more expensive than plain walls. The expense of washing windows is an appreciable percentage of the cost of gas or electricity. And there is window-breakage to be considered.

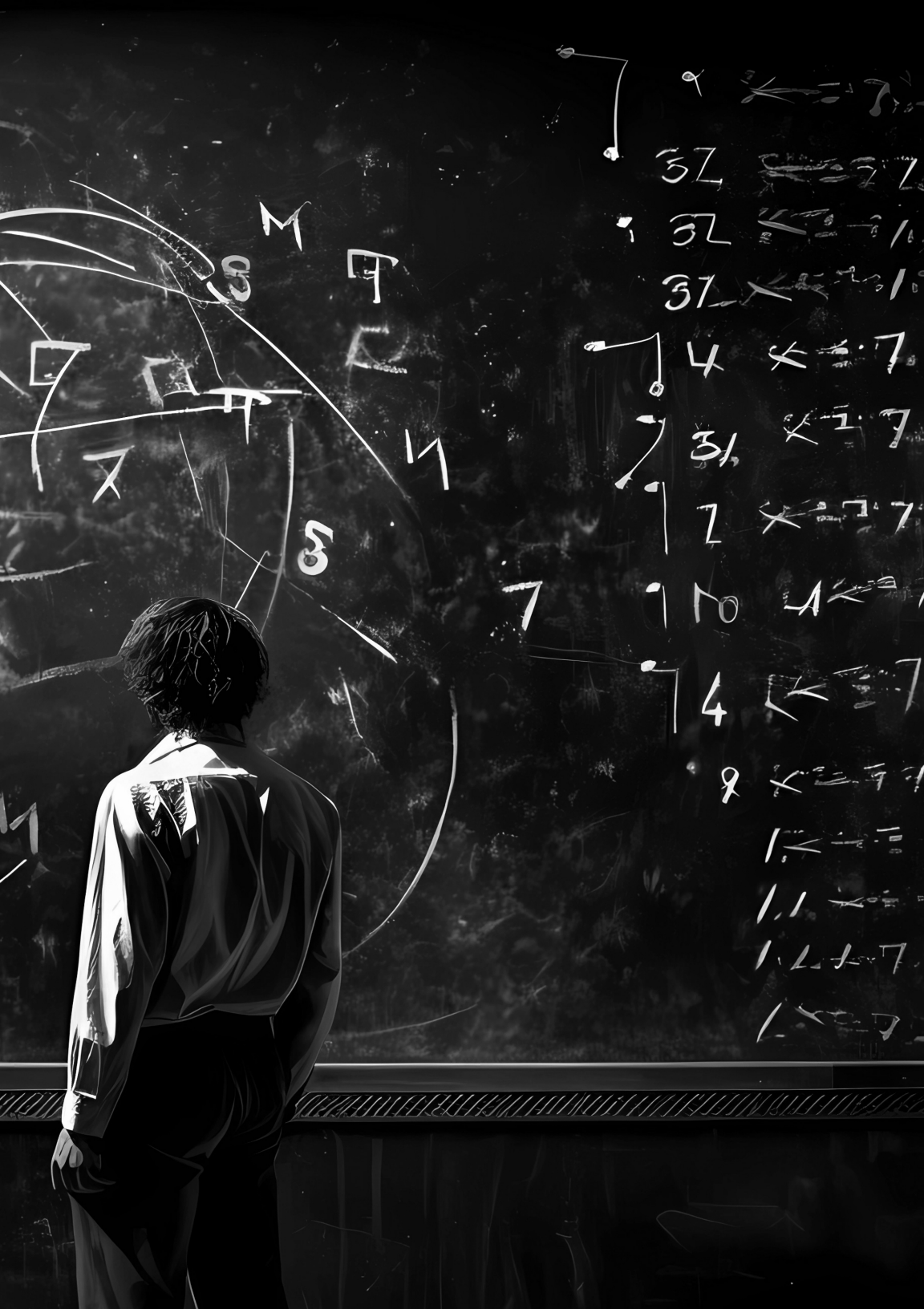
In the more elaborate buildings of the congested portions of cities, daylight is satisfactory a lesser number of hours than in the outlying districts. In some stores, offices, and factories artificial light is used throughout the day. Still, the daylighting-equipment is installed and maintained. Furthermore, when it is considered that much expensive area is given to light-courts and much valuable wall space to windows, it is seen that the cost of daylight in congested cities is in reality considerable. Of course, the daylighting-equipment has value in ventilating, but ventilation may be taken care of in a very satisfactory manner as a separate problem.

The cost of skylights in museums and other large buildings is far greater than that of ordinary ceilings and walls, and the extra allowance for heating is appreciable. The expense of maintenance of some skylights is considerable.

Thus it is seen that the cost and maintenance of daylighting-equipment, the loss of valuable rental space and of wall area, and the increased expense of heating are

factors which challenge the statement that daylight costs nothing. In fact, it is not surprising to find that occasionally the elimination of daylighting—the reliance upon artificial light alone—has been seriously contemplated. When the possibilities of the latter are considered, it is reasonable to expect that it will make greater and greater inroads and that many buildings of the future will be equipped solely with artificial-lighting systems.

NATURALLY, WITH THE TREMENDOUS DEVELOPMENT OF ARTIFICIAL LIGHT DURING THE PRESENT AGE, A NEW PROFESSION HAS ARISEN. The lighting expert is evolving to fill the needs. He is studying the problems of producing and utilizing artificial illumination. He deals with the physics of light-production. His studies of utilization carry him into the vast fields of physiology and psychology. His is a profession which eventually will lead into numerous highways and byways of enterprise, because the possibilities of lighting extend into all those activities which make their appeal to consciousness through the doorway of vision. These possibilities are limited only by the boundaries of human endeavor and in the broadest sense extend even beyond them, for light is one of the most prominent agencies in the scheme of creation. It contributes largely to the safety, the efficiency, and the happiness of civilized beings and beyond all it is a powerful civilizing agency.



03 LIGHT AND FUTURE

IN VIEWING THE DEVELOPMENT OF ARTIFICIAL LIGHT

In viewing the development of artificial light, it is natural to look into the future. Jules Verne possessed the advantage of being able to write into fiction what his riotous imagination dictated, and so much of what he pictured has come true that his success tempts one to do likewise in prophesying the future of lighting. Surely a forecast based alone upon the past achievements and the present indications will fall short of the actual realizations of the future! If the imagination is permitted to view the future without restrictions, many apparently far-fetched schemes may be devised. It may be possible to turn to nature's supply of daylight and to place some of it in storage for night use.

DEVELOPMENT

The fictionist need not heed the scientist's inquiry as to how this daylight would be bottled. Instead of giving time to such inquiries he would pass on to another scheme, whereby earth would be belted with optical devices so that day could never leave. When the sun was shining in China its light would be gathered on a large scale and sent eastward and westward in these great optical "pipe-lines" to the regions of darkness, thus banishing night forever. The writer of fiction need not bother with a consideration of the economic situation which would demand such efforts. This line of conjecture is interesting, for it may suggest possibilities toward which the present trend of artificial lighting does not point; however, the author is constrained to treat the future of light-production on a somewhat more conservative basis.

At the present time the light-source of chief interest in electric lighting is the incandescent filament lamp; but its luminous efficiency is limited, as has been shown in a previous chapter. When light is emitted by virtue of its temperature much invisible radiant energy accompanies the visible energy. The highest luminous efficiency attainable by pure temperature radiation will be reached when the temperature of a normal radiator reaches the vicinity of 10,000°F. to 11,000°F. The melting-points

of metals are much lower than this. The tungsten filament in the most efficient lamps employing it is operating near its melting-point at the present time. Carbon is a most attractive element in respect to melting-point, for it melts at a temperature between 6000°F. and 7000°F. Even this is far below the most efficient temperature for the production of light by means of pure temperature radiation. There are possibilities of higher efficiency being obtained by operating arcs or filaments under pressure; however, it appears that highly efficient light of the future will result from a radical departure.

SCIENTISTS ARE BECOMING MORE AND MORE INTIMATE WITH THE STRUCTURE OF MATTER. They are learning secrets every year which apparently are leading to a fundamental knowledge of the subject. When these mysteries are solved, who can say that man will not be able to create elements to suit his needs, or at least to alter the properties of the elements already available?

If he could so alter the mechanism of radiation that a hot metal would radiate no invisible energy, he would have made a tremendous stride even in the production of light by virtue of high temperature. This property of selective radiation is possessed by some elements to a slight degree, but if treatment could enhance this property, luminous efficiency would be greatly increased. Certainly the principle of selectivity is a byway of possibilities.

A careful study of commonplace factors may result in a great step in light-production without the creation of new elements or compounds, just as such a procedure doubled the luminous efficiency of the tungsten filament when the gas-filled lamp appeared. There are a few elements still missing, according to the Periodic Law which has been so valuable in chemistry. When these turn up, they may be found to possess valuable properties for light-production; but this is a discouraging byway.

It is natural to inquire whether or not any mode of light-production now in use has a limiting luminous efficiency approaching the ultimate limit which is imposed by the visibility of radiation. The eye is able to convert radiant energy of different wave-lengths into certain fixed proportions of light. For example, radiant energy of such a wave-length as to excite the sensation of yellow-green is the most efficient and one watt of this energy is capable of being converted by the visual apparatus into about 625 lumens of light. Is this efficiency of conversion of the visual apparatus everlastingly fixed? For the answer it is necessary to turn to the physiologist, and doubtless he would suggest the curbing of the imagination.

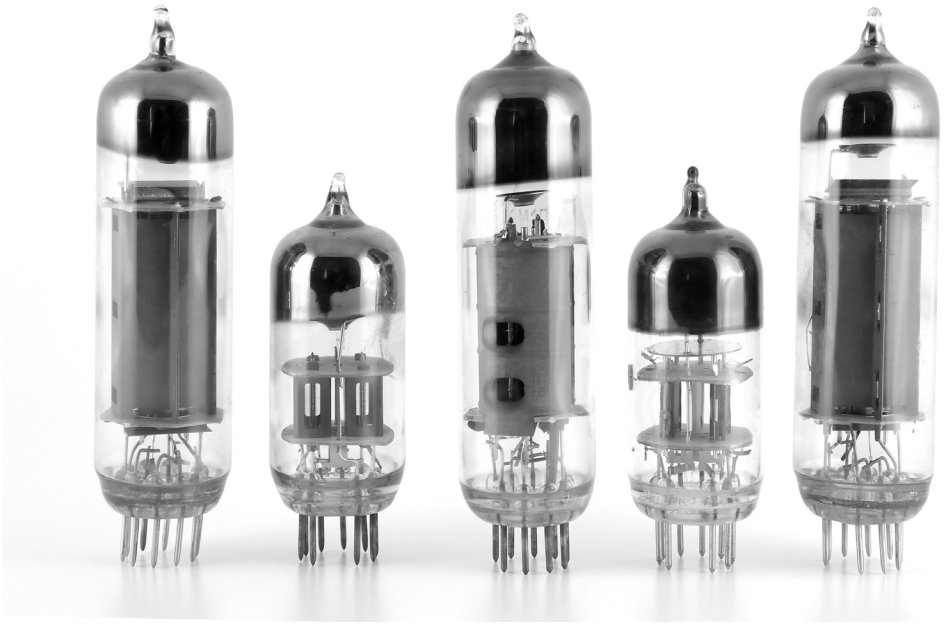
But is it unthinkable that the visual processes will always be beyond the control of man? However, to turn again to the physics of light-production, there are still several processes of producing light which are appealing.

Many years ago Geissler, Crookes, and other scientists studied the spectra of gases excited to incandescence by the electric discharge in so-called vacuum tubes. The gases are placed in transparent glass or quartz tubes at rather low pressures and a high voltage is impressed upon the ends of these tubes. When the pressure is sufficiently low, the gases will glow and emit light. Twenty-eight years ago, D. McFarlan Moore developed the nitrogen tube, which was actually installed in various places. But there is such a loss of energy near the cathode that short "vacuum" tubes of this character are very inefficient producers of light. Efficiency is greatly increased by lengthening the tubes, so Moore used tubes of great length and a rather high voltage. As a tube of this sort is used, the gas gradually disappears and it must be replenished. In order to replenish the gas, Moore devised a valve for feeding gas automatically. An advantage of this mode of light-production is that the color or quality of the light may be varied by varying the gas used. Nitrogen yields a pinkish light; neon an orange light; and carbon dioxide a white light. Moore's carbon-dioxide tube is an excellent substitute for daylight and has been used for the discrimination of colors where this is an important factor. However, for this purpose devices utilizing color-screens which alter the light from the tungsten lamp to a daylight quality are being used extensively.

The vacuum-tube method of producing light has an advantage in the selection of a gas among a large number of possibilities,

and some of the color effects of the future may be obtained by means of it. Claude has lately worked on light-production by vacuum tubes and has combined the neon tube with the mercury-vapor tube. The spectrum of neon to a large extent compensates for the absence of red light in the mercury spectrum, with a result that the mixture produces a more satisfactory light than that of either tube. However, this mode of light-production has not proved practicable in its present state of development. Fundamentally the limitations are those of the inherent spectral characteristics of gases. Doubtless the possibilities of the mechanisms of the tubes and of combining various gases have not been exhausted. Furthermore, if man ever becomes capable of controlling to some extent the structure of elements and of compounds, this method of light-production is perhaps more promising than others of the present day.

THERE IS ANOTHER ATTRACTIVE METHOD OF PRODUCING LIGHT AND IT HAS NOT ESCAPED THE WRITER OF FICTION. H. G. Wells, with his rare skill and with the license so often envied by the writer of facts, has drawn upon the characteristics of fluorescence and phosphorescence. In his story "The First Men in the Moon," the inhabitants of the moon illuminate their caverns by utilizing this phenomenon. A fluorescent liquid was prepared in large quantities. It emitted a brilliant phosphorescent glow and when it splashed on the feet of the earth-men it felt cold, but it glowed for a long time. This is a possibility of the future



and many have had visions of such lighting. If the ceiling of a coal-mine was lined with glowing fireflies or with phosphorescent material excited in some manner, it would be possible to see fairly well with the dark-adapted eyes.

THIS LEADS TO THE CLASS OF PHENOMENA INCLUDED UNDER THE GENERAL TERM "LUMINESCENCE."

The definition of this term is not thoroughly agreed upon, but light produced in this manner does not depend upon temperature in the sense that a glowing tungsten filament emits light because it is sufficiently hot. A phosphorus match rubbed in the moist palm of the hand is seen to glow, although it is at an ordinary temperature. This may be termed "chemi-luminescence." Sidot blende, Balmain's paint, and many other compounds, when illuminated with ordinary light, and especially with ultra-violet and violet rays, will continue to glow for a long time. Despite their brightness they will be cold to the touch. This phenomenon would be termed "photo-luminescence," although it is better known as "phosphorescence." It should be noted that the latter term was carelessly originated, for phosphorus has nothing to do with it. The glow of the Geissler tube or electrically excited gas at low pressure would be an example of "electro-luminescence." The luminosity of various salts in the Bunsen-flame is due to so-called luminescence and there are many other examples of light-production which are included in the same general class. Inasmuch as light is emitted from comparatively cold bodies in these cases, it is popularly known as "cold" light.

There are many instances of light being emitted without being accompanied by appreciable amounts of invisible radiant energy and it is natural to hope for practical possibilities in this direction. As yet little is known regarding the efficiency of light-production by phosphorescence. The luminous efficiency of the radiant energy emitted by phosphorescent substances has been studied, but it seems strange that among the vast works on phosphorescent phenomena, scarcely any mention is made of the efficiency of producing light in this manner. For example, assume that phosphorescent zinc sulphide is excited by the light from a mercury-arc. All the energy falling upon it is not capable of exciting phosphorescence, as may be readily shown.

Assuming that a known amount of radiant energy of a certain wave-length has been permitted to fall upon the phosphorescent material, then in the dark the latter may be seen to glow for a long time. An interesting point to investigate is the relation of the output to input; that is, the ratio of the total emitted light to the total exciting energy. This is a neglected aspect in the study of light-production by this means.

The firefly has been praised far and wide as the ideal light-source. It is an efficient radiator of light, for its light is "cold"; that is, it does not appear to be accompanied by invisible radiant energy. But little is said about its efficiency as a light-producer. Who

knows how much fuel its lighting-plant consumes? The chemistry of light-production by living organisms is being unraveled and this part of the phenomenon will likely be laid bare before long. For an equal amount of energy radiated, the firefly emits a great many times more light than the most efficient lamp in use at the present time, but before the firefly is pronounced ideal, the efficiency of its light-producing process must be known.

THERE ARE MANY WAYS OF EXCITING PHOSPHORESCENCE AND FLUORESCENCE, the latter being merely an unenduring phosphorescence, which ceases when the exciting energy is cut off. Ultra-violet, violet, and blue rays are generally the most effective radiant energy for excitation purposes. X-rays and the high-frequency discharge are also powerful excitants. As already stated, virtually nothing is known of the efficiency of this mode of light-production or of the mechanism within the substance, but on the whole it is a remarkable phenomenon.

Radium is also a possibility in light-production and in fact has been practically employed for this purpose for several years. It or one of its compounds is mixed with a phosphorescent substance such as zinc sulphide and the latter glows continuously. Inasmuch as the life of some of the radium products is very long, such a method of illuminating watch-dials, scales of instruments, etc., is very practicable where they are to be read by eyes adapted to darkness and consequently highly sensitive to light. Whether or not radium will be manufactured by the ton in the future can only conjectured.

Owing to the limitations imposed by physical laws of radiation and by the physiological processes of vision the highest luminous efficiency obtainable by heating solid materials is only about 15 per cent. of the luminous efficiency of the most luminous radiant energy. At present there are no materials available which may be operated at the temperature necessary to reach even this efficiency.

GREAT PROGRESS IN THE FUTURE OF LIGHT-PRODUCTION AS INDICATED BY PRESENT KNOWLEDGE APPEARS TO LIE IN THE PRODUCTION OF LIGHT WHICH IS UNACCOMPANIED BY INVISIBLE RADIANT ENERGY. At present such phenomena as fluorescence, phosphorescence, the light of the firefly, chemi-luminescence, etc., are examples of this kind of light-production. Of course, if science ever obtains control over the constitution of matter, many difficulties will disappear; for then man will not be dependent upon the elements and compounds now available but will be able to modify them to suit his needs.

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