SCIENCE AND ART OF ILLUMINATION

(PART 1)

Serial 2749 A Edition 1

LIGHT FOR SEEING

INTRODUCTION

1. The purpose of this lesson is to give the student a broader view of lighting in its relation to human welfare, that he may sense the vast opportunity he has, through this agency, of conserving eyesight, of making tasks easier and safer, and of contributing to the well-being of all who use their eyes in serious seeing.

It can be stated, conservatively, that present-day needs, logical and economical, for better lighting in our schools, offices, factories, and homes far exceed the present total capacity of existing electrical systems. The greater proportion of energy operated is now used for power and hundreds of other electrical applications besides lighting. In addition are the many uses of light for its artistic and decorative values, for advertising and attraction, for recreation and health, all of which can stand on their own merits from the standpoint of their economic worth.

Whether modern commerce and industry could have progressed to their present status without electric light is questionable; however, one needs little imagination to picture the confusion that would exist if modern civilization were forced to go back to the old flame sources of illumination that prevailed throughout the many centuries of man's existence. Modern industry as such would cease, streets would be unsafe, movie theaters would close, transportation would be crippled—yet the general and widespread

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1934 Sodium-Vapor Lamp
High Intensity Mercury-Vapor Lamp

North Skylight

Artificial Daylight

Motion Picture

Commercial Sign

and

Decorative

Railway

Home

Aviation

Mobile Color

Floodlighting

Aircraft

Surgical

Dental

Industrial

Automotive

Flashlight

Switch Board

Street

Traffic Signals

Projection

1923-1927
NEON TUBE

1920

1913 GAS-FILLED LAMPS
20 LUMENS PER WATT

1912

1911 DRAWN TUNGSTEN FILAMENT **MAZDA**
10 LUMENS PER WATT

1907

1907 PRESSED TUNGSTEN FILAMENT
8 LUMENS PER WATT

1906

1906 TANTALUM FILAMENT
5 LUMENS PER WATT

1905

1905 GEM OR METALLIZED CARBON FILAMENT
4 LUMENS PER WATT

1901 MERCURY-VAPOR LAMP

MANTLE

1893 CELLULOSE FILAMENT
3.3 LUMENS PER WATT

1880

1881 FIRST COMMERCIAL LAMP
1.6 LUMENS PER WATT

1879 EDISON'S FIRST SUCCESSFUL LAMP
1.4 LUMENS PER WATT

1870

GAS

1850

KEROSENE

CAMPHENE

1800

CANDLE

1600

OIL LAMP

400 A.D.

METAL LAMP

3000 B.C.

STONE LAMP

TORCH

A pictorial history of artificial light

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FIG. 1

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use of electric light has come about only during the last generation. So pronounced has been the effect of electric lighting on our methods of living that one might erroneously conclude that present lighting conditions are reasonably adequate and that there might be little to gain by further improvements.

The developments and influences that have led up to the present-day status of illumination will be traced briefly, and from this background an attempt will be made to perceive the trends of practice and project them into the future. The student can thus relate in his own mind the factors which influence progress. In this process, he includes a consideration of the factors involved in the development of technical devices. In addition, and of more importance, is a consideration of the factual data and new knowledge that must be brought to public acceptance and attuned to the social and economic conditions that are likely to prevail in the future.

CHANGING ASPECTS OF LIGHTING PRACTICE

2. Expanding Field of Illumination.—The field of illumination is an ever-expanding one. It offers opportunity for the exercise of many diverse talents. The practice of illuminating engineering as a science, and the employment of light in its full significance in the realm of art and decoration, quickly overflows the rather restricted bounds of electrical engineering, of which it has been considered an essential by-product. That is to say, the principal concern of the electrical engineering student lay in the theory and practice of electrical generation and transmission and his interest in lighting generally ended at the lamp socket in the mere production of light. As a matter of fact, it is easy to confirm this statement in the overwhelming majority of cases on every hand where illumination practice is still served by this early conception—a lamp in a socket, either bare or with the most elementary type of shading or diffusing equipment and with little consciousness of the relation of light for seeing. The relatively few examples of advanced practice which can be pointed to today merely demonstrate the lack of knowledge, responsibility, and courage to depart from traditional and primitive views. A study of the factors mentioned points the need for a

trained group of men to handle specification of lighting based on the science and art which are inherent in the proper utilization of light.

3. Lighting Engineer's Job.—The lighting engineer's job begins at the lighting socket, or more properly, perhaps, at the service connection of the building, for indeed he can, in the present state of development and with technical facilities of the electric utilities for expansion, take for granted an adequate and dependable supply of electrical energy. He must be concerned, however, with the wiring arrangements beyond the meter, since the adequacy of the wiring has much to do with the economy of the lighting installation and its flexibility; furthermore, the control devices that may be used dictate to a large extent the convenience and adaptability of the lighting to its full and proper use. These matters are covered in more detail in other lessons.

SCIENTIFIC ASPECTS OF ILLUMINATION

PRODUCTION OF LIGHT

4. The scientific aspects of illumination involve not only the production of light but also control of light and specification of lighting.

Obviously, the student of lighting should be familiar with the newest developments, characteristics, and adaptability of all light sources. The technical development of incandescent lamps within the last decade has brought to the field of lighting service many new types to meet the ever-expanding applications. The departure from historical flame sources and the broadening fields of modern lamp application are shown pictorially in Fig. 1. New lighting ideas and new trends of practice continue to dictate new and improved lamp construction, new sizes, and oftentimes, lamps of special operating characteristics.

The types of electric lamps developed recently are described at the end of this lesson. These new light sources, each with its own peculiar operating characteristics and spectral quality of light, will greatly broaden the practice of illuminating engineering, especially as their practical standards are improved.

CONTROL OF LIGHT

5. Little need be said here on the subject of control of light, since other lessons cover fairly completely the reflecting characteristics of various materials and methods of light control. For many years the lighting profession has devoted its principal study to control and utilization of light until the scientific principles back of them are well known. However, new materials are constantly being developed for application to lighting problems. For example, various plastics are now in use, as well as improved reflecting surfaces such as the new finish for aluminum. This finish increases the *reflection factor from around 65 per cent. for ordinary aluminum to over 80 per cent. and at the same time provides a finish that appears to be durable and fairly permanent, even when exposed to outdoor atmospheric conditions.

Similarly, the increased trend toward architectural lighting in its many forms, using panels of glass of flashed opal, frosted, configurated, molded, prismatic or any other of the many glasses on the market, also opens up new fields for study. In this same connection it becomes clear that the lighting specialist must know more about structural details when considering lighting as a built-in feature or part of the architecture of a building, and this fact immediately suggests a much closer relationship between the lighting man and the architect. The importance of this relationship has long been stressed even for the relatively simple requirements encountered in past practice, but it is evident in the trend toward built-in lighting that close cooperation in the future will be absolutely essential.

The student of illumination should be on the alert for exhaustive details on all new developments, since they are the tools with which he must work, and it is only through his knowledge that he will be able to appraise and evaluate them in connection with any specific lighting problem.

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*The percentage of light falling on an object that is reflected by the object is called its reflection factor.

SPECIFICATION OF LIGHTING

6. General Discussion.—When discussing specification of lighting it is necessary to get out of the realm of exact physical science such as prevails in dealing with light sources and control of light, and emerge into a totally different realm, namely, that dealing with human beings. The new realm entered is that of psychological values, of likes and dislikes, of habits and notions, and human reactions, and where lighting practice is influenced by artistic and decorative concepts few rules can be set down. The specification of lighting may be divided in a fairly logical way into two principal divisions: (*a*) Light for seeing; (*b*) light for beauty and decoration.

In the lighting-for-seeing division the object is to provide lighting adequate in both quantity and quality to best serve the needs of the eye, yet in the actual details of installation, equipment and method may be guided by artistic and aesthetic considerations; particularly is this true in commercial and residential lighting. These features will be discussed more in detail in another lesson, and it will be the purpose, in the pages that follow, to devote immediate study to the science of seeing.

The eye is a remarkable instrument and will operate throughout a wide variation in illumination levels ranging in nature from moonlight to noonday summer sunlight, the foot-candle value of the latter being about 600,000 times greater than that of full moonlight. One scarcely needs to be reminded that any detailed seeing under moonlight is extremely difficult compared to the clarity of vision, comfort, and ease of seeing out of doors in the daytime. In artificial lighting practice, advantage has too often been taken of the fact that the eye will serve over a wide range of lighting values. Illumination standards of the past have had little scientific foundation, being based largely on progress in lamp and equipment development, electric-light rates, and traditional notions of people who inherited from the days of candles and other flame sources, the idea of the necessity of strict economy in the use of artificial lighting. While it is true that every step of progress in the more efficient production of light has been accepted to increase the amount of light used rather than

to reduce the cost, this serves only to emphasize the fact that the eye has never been quite satisfied with the comparatively meager amounts of artificial light compared with the abundance of light which nature provides. More important, however, is the conclusive evidence that our eyes are being crippled by conditions of long continued use under improper lighting conditions, leaving a trail of social and economic disadvantages of such consequence as greatly to affect human welfare and happiness. Because of the broader significance and implication of lighting practice in

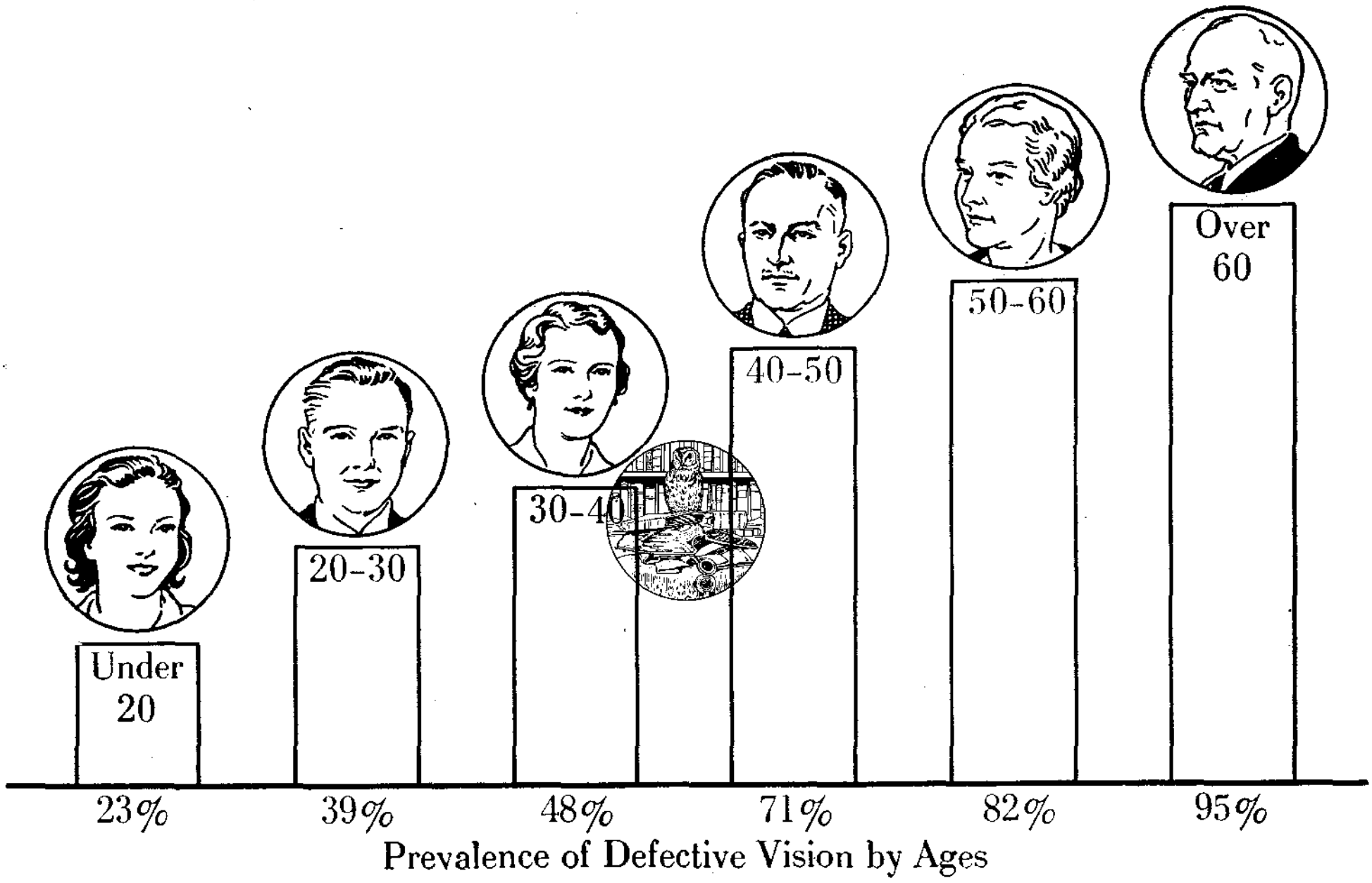


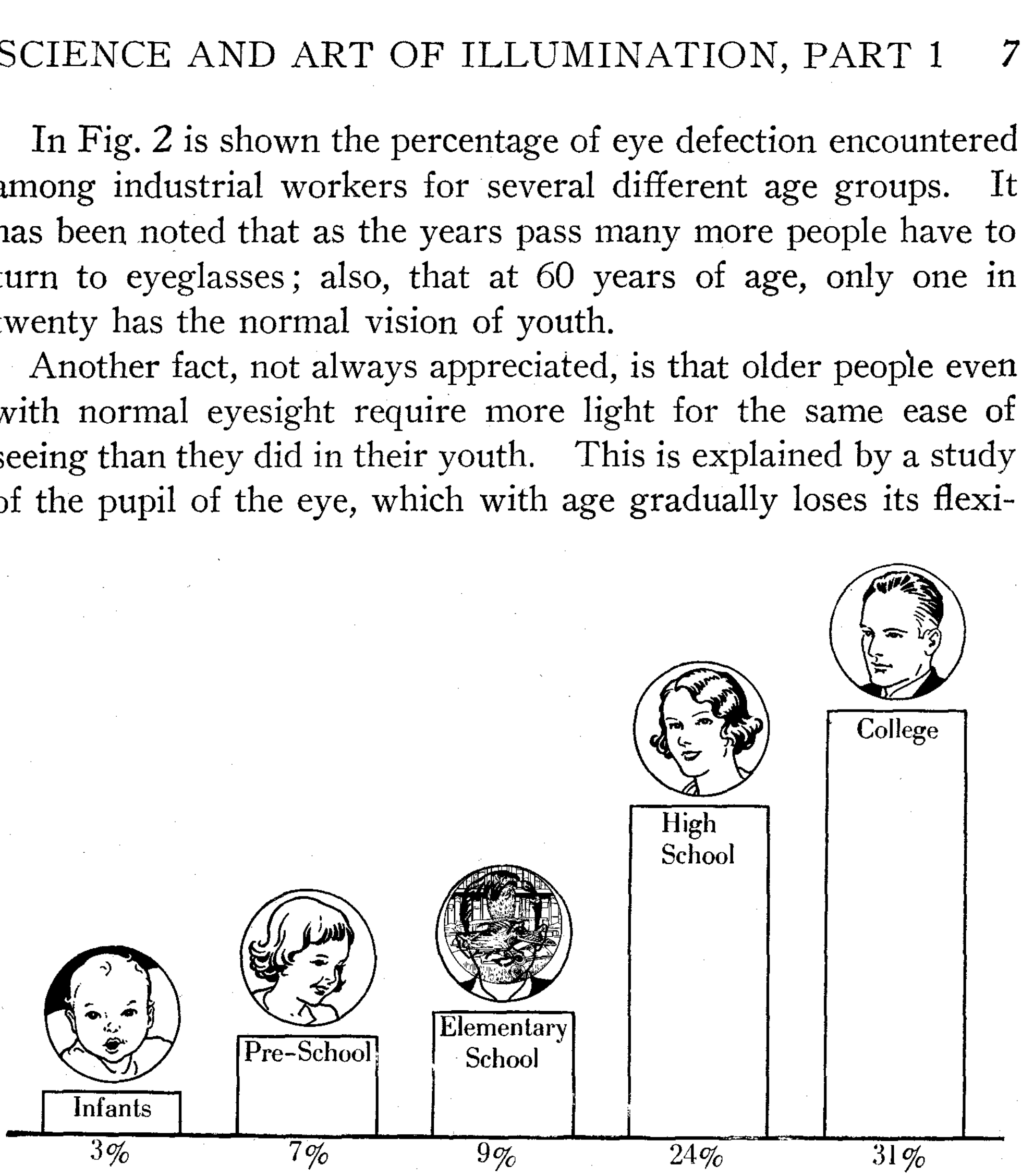
FIG. 2

modern civilization, and because the electrical industry and its agents—the illuminating engineer and lighting specialist—are recognizing a greater responsibility than ever before, an attempt is made here to summarize for the student many of the observations reflecting the status of lighting in its relation to the conservation of eyesight, and to present pertinent scientific data and knowledge on which specifications for adequate lighting can be determined.

7. **Relation of Lighting to Eyesight and Seeing.**—It is estimated that more than 15,000,000 people in this country wear glasses, either all or part of the time, and of our adult population an equal number have uncorrected faulty vision.

In Fig. 2 is shown the percentage of eye defection encountered among industrial workers for several different age groups. It has been noted that as the years pass many more people have to turn to eyeglasses; also, that at 60 years of age, only one in twenty has the normal vision of youth.

Another fact, not always appreciated, is that older people even with normal eyesight require more light for the same ease of seeing than they did in their youth. This is explained by a study of the pupil of the eye, which with age gradually loses its flexi-



Progress of nearsightedness in schools and colleges

FIG. 3

bility or power of accommodation. The eye of the older person therefore lets in much less than the normal amount of light. To get the same brightness of picture on the retina, a person 50 years of age requires double the illumination that a person 20 years of age requires.

In Fig. 3 are represented the results of a study of the progress of nearsightedness of school children and college students, showing that, with increasing eye usage for close concentration, eye defects become appallingly serious in their frequency. Eyeglasses have long been the badge of the overstudious person, and the cartoonist need only add eyeglasses to identify the burner of midnight oil. The foregoing data and, in fact, most of the con-

ditions of lighting and seeing reviewed here will serve largely to recall the student's own observations and experiences.

While skillful fitting of glasses will do much to help overtaxed and faulty eyes, yet, at best, an eye specialist can only help a pair of defective eyes; he cannot bring them back to normal. Many times even glasses are inadequate, and then it becomes a process of periodic refitting and adjustment to keep the eyes seeing their best. The wearing of glasses—aptly likened to using crutches—has become commonplace, but if 40 per cent. of the people on the street were using crutches, one would think something was wrong with the world. The scientific approach to lighting today is concerned with proper illumination as a means of preventing faulty eyesight, and to so affect the thinking of all people responsible for lighting installations, and bring about an understanding on the part of all users of light that conditions of seeing will gradually be improved.

Our eyes are our most priceless possession; most of our knowledge and impressions are gained through the eyes, and most of our activities are governed by seeing. The human race even think visually. Is it any wonder, then, that the leaders in lighting science and thought are setting about to attack conditions that affect the conservation of eyesight with as much concern and a feeling of responsibility as health authorities 30 years ago attacked the menace of malerial fever in the mosquito-infested swamps of the Panama Canal Zone.

8. Eyestrain Depends on Occupation.—There is no historical proof from the ages past that early man retained throughout his lifetime more perfect eyesight than do our people of the present time; all reasoning, however, points to this conclusion. Evidence is available that the normal eye today is just as sharp and as good a visual tool as were the eyes of people born 5,000 years ago. In the earliest writing of the ancient Egyptian astronomers, it is recorded that the seventh of the principal stars of the constellation of Pleiades (the seven sisters) was barely discernible to the experienced eye. The trained vision of the sailor or hunter is just as successful today in picking out this same faintly visible star.

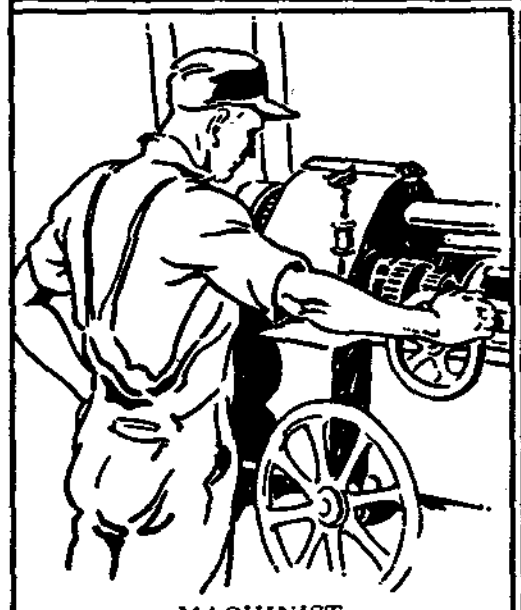
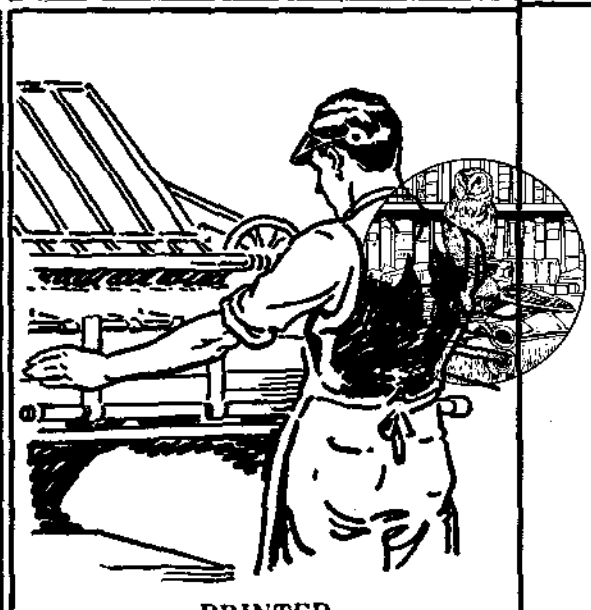
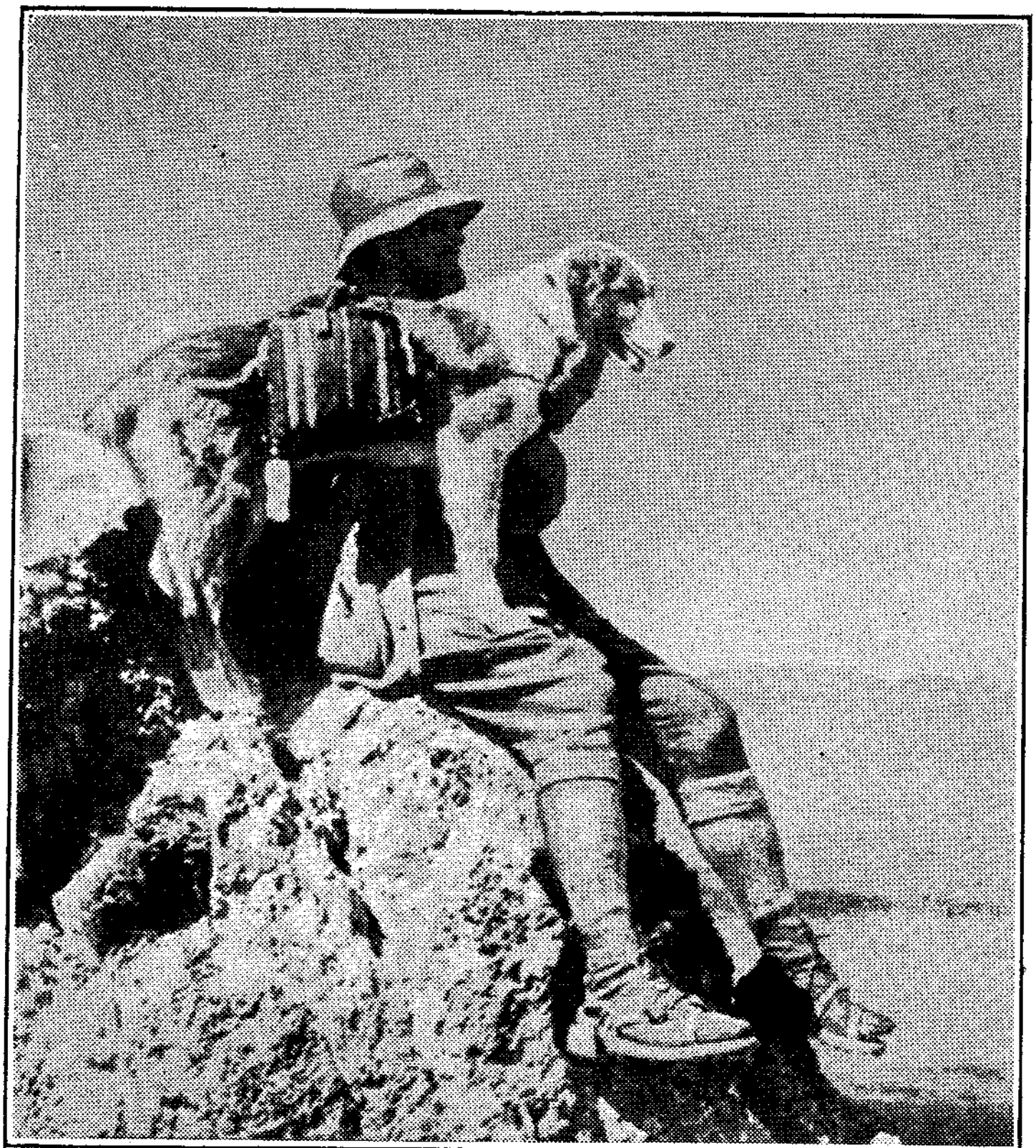
		Percentage of Persons in each group	Percentage with Ocular or Eyestrain Diseases
 FARMER	 COMMON LABORER	40	1–20
 CARPENTER	 PAINTER	10	20–40
 MACHINIST	 PRINTER	10	40–60
 HOUSEWIFE	 PROFESSOR	20	60–80
 DRAFTSMAN	 STENOGRAPHER	20	80–100

FIG. 4

To substantiate the conclusion that our generation and generations of the immediate past are wearing their eyes out too soon, owing to conditions which advanced civilization and modern living have prescribed, Fig. 4 should be noted as showing the results of the use and abuse of the eyes. It presents survey data showing groupings of various occupations according to frequency of eye strain. It is found, as indicated in Fig. 4, that outdoor workers, as a class, are singularly free from eye defects compared to indoor workers, who show a progressively higher percentage of defects. For example, of the farmers and common laborers who constitute 40 per cent. of the persons in each group considered, only 1 to 20 per cent. have ocular or eyestrain diseases, while of the draftsmen and stenographers, who constitute 20 per cent. of the persons in each group considered, from 80 to 100 per cent. have ocular or eyestrain diseases. The percentage of defective eyes increases as the amount of concentrated vision to which they are subjected also increased.

While 40 per cent. of women are revealed to have a small percentage of eye defects, and this seems definitely related to the fact that their daily occupation does not involve serious visual work, it is also true that great numbers of these same people spend their evening hours with the daily newspaper, in study, or in recreational activities involving extra use of the eyes under much less favorable lighting than they had outdoors. This statistical record from our own generation leads to the belief that historical people did not suffer eyestrain defects as do our later generations because they were not confronted with conditions which caused eyestrain, and consequent eye defects.

For the thousands and thousands of years during which man has been developing, he has been essentially an outdoor creature. His eyes, for instance, were built to function under the high illumination of daylight. He used his eyes primarily for long-distance seeing and when the sun went down, he went to bed. But within the last two generations, the inhabitants of civilized countries have developed all kinds of indoor-located machinery, which must be run night and day, on dark days as well as sunny ones. Therefore the necessity of sufficient illumination at all times and in all places in order to prevent undue eyestrain.



(a)

(b)

FIG 5