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lysts may be applied for similar reasons. The catalyst used commercially is reduced nickel or copper-nickel produced by heating the formate or, on a carrier, by hydrogen-reduction of the basic carbonates precipitated on diatomaceous earth or carbon. Raney nickel may also be used. Hydrogenation may also be carried out continuously, using a stationary catalyst. The hydrogen used may be produced electrolytically or by the shaft and other processes. It must be free from catalyst poisons.

Deodorization—the process of blowing live steam through the oil at temperatures up to 225° C. and under a vacuum of 5 to 50 mm. The odoriferous matters are carried off by the steam.

Shortening—made by subjecting fats to a rapid cooling either in a thin film on a revolving, internally cooled steel drum from which the semi-solid material is scraped off and homogenized (texturated), or by passing through an externally cooled cylinder under agitation and pressure. The material emerges through an extrusion valve whereby homogenization is accomplished. In both cases a certain amount of air or nitrogen is incorporated for the purpose of improving texture, plasticity and color.

NIGHT VISION

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Dark adaptation is the ability of the eye to adjust or adapt its visual mechanism to darkness. The phenomenon may be observed when passing from the street, with noonday illumination, into the movie theater. At first nothing is seen in the darkened room, but as the eye adapts itself, the benches, chairs and walls begin to be discerned. As time goes on, objects become clearer and more definite, and the eyes become adjusted or adapted to the environmental illumination. In turn, in passing from the darkened surroundings of the theater to the brightly illuminated street, the eyes must become *light*-adapted. One often experiences the effects of glare and the symptoms of photophobia. Hence, the most adaptable eyes and those of superior quality in military science, such as night flying, possess *tolerance* for strong illumination and retinal *sensitivity* to low illuminations.

PHYSIOLOGY OF DARK ADAPTATION

The retinas of most vertebrates contain two different types of receptors—cones and rods. Hence the retina of the vertebrate may be considered as a dual rather than a single sense organ. Structurally, the center of the human eye, the fovea centralis, is occupied almost exclusively by cones, whereas the remainder of the retina contains cones and rods, with rods becoming increasingly predominant as the survey is made from center to periphery. The most efficient vision under high illuminations is at the center (macúla) of the retina, whereas at low illuminations the peripheral areas are more effective and serviceable than the center. Hence the idea of dual visual functions associates, on the one hand, vision under high illuminations with the cones and, on the other hand, vision under low intensities with the rods. Furthermore, since color is discerned best at high intensities and not at all at very low intensity of light, the cones may be considered as specific receptors for color and the rods as general receptors of light only. Cones, therefore, are concerned primarily with form and color (*photopic* or day vision); rods with the sense of light (*scotopic* or night vision). Hence twilight or night vision is effected by the rods through the medium of the visual purple—rhodopsin.

In recent years much evidence has been produced experimentally to support the duplicity theory of retinal function as first proposed by Schultze, 1866 (**12**), and Parinaud (**11**), and finally rounded out by von Kries, 1895 (**8**). It is claimed by the proponents of this theory that strong light (ordinary daylight) bleaches the visual purple and that the rapidity with which the rod function (scotopic vision) reappears in a darkened room depends on the rapidity of regeneration of the visual purple. In general support of the duplicity theory is the fact that animals which forage for food during the day, such as birds and certain types of lizard, have a preponderance of cones, whereas the animals which prowl in the night, such as bats, mice and night owls, show an excess of rods.

In the human fovea, which is rod free and used in photopic vision, there are about 150,000 cones. Extending outward to the periphery is an increasing number of rods with a corresponding diminution in the number of cones. The maximal rod area (concerned with night vision) extends from the extreme periphery to about 15 to 20 degrees from the macula. The ratio of rods to cones in the human retina is about 20:1. There are about 125,000,000 rods as compared to 6,500,000 cones. Clear, distinct vision with an appreciation of color is dependent on central vision, with its richness in cones and adequate use of high illumination. Appreciation of minimal quantities of light is dependent on peripheral vision, with its richness in rods and superior use of very low illuminations. Hence one locates the black cat in the black night far better by rod than by cone vision; under such circumstances one sees better out of the "corner of one's eye."

The change-over between rod vision (low brightness levels) and cone vision (high brightness levels) takes place in the range of 0.1 to 0.01 millilambert (practically same as foot-candle). Even in the range between 1.0 and 0.1 millilambert, where cone vision is operative, deterioration of visual acuity and of discrimination of intensity with lowering of the brightness level becomes quite noticeable. The degree of sensitivity which develops in the retina after a rest in the dark is worthy of note and, in the language of the street, is "something to marvel at." After ten or twelve hours in darkness, the threshold brightness reaches a lower limit of 0.000,001 millilambert if white light is used. Yet that same retina, after exposure to bright light for a few minutes, enters a state which is referred to as light-adapted, in which its threshold (that is, the smallest amount of light which will produce the sensation of vision or the threshold of photopic vision) has risen to about 0.005 millilambert and in this state the retina is capable in general of accepting without injury to itself energies as high as 16,000 millilamberts. In other words, its threshold has increased to about 5,000 times the threshold of the dark-adapted eye, and the maximal brightness that is acceptable by the completely light-adapted retina is more than 10,000,000,000 times the threshold of sensitivity of the completely (after several hours) dark-adapted eye. The most striking thing about the change of visual threshold, as one enters and remains in a dark room, is its range; it can easily cover a gamut from 100,000 units of light intensity at the beginning to one unit at the end of dark adaptation.

CRITERIA FOR PRECISE MEASUREMENTS OF DARK ADAPTATION

In brief review of facts and statements which cannot be given in detail within the limitations of this communication (**13**), let it be stated categorically that there are at least eight specifications which must be made in order that measurements of dark adaptation may be precise numerically and quantitatively valid. These conditions are:

1. Accuracy, constancy and reproducibility of physical measurements and of various portions of the ensembles. There is considerable conflict of data and hence, presumably, of conclusions in the literature which can be traced to poorly constructed apparatus, inaccurate calibrations and improper use of ensembles.

2. The intensity of the light used for light adaptation. Various investigators have used as low as 100 to 200 millilamberts, others have used 1,500 millilamberts, and a few have employed 3,000 millilamberts. The higher the preadapting light intensity the more marked and longer the period of cone adaptation and, therefore, the longer the period of recovery of rods or time of reaching a fairly uniform rod threshold level.

3. The duration of exposure to light before starting measurement on the course of dark adaptation. Since the total luminous energy (E) received is equal to the intensity or brightness of illumination (I) multiplied by the time (t), it follows that, in general, the response level (R) varies as log $I \cdot t$, or

$$R = k \log I \cdot t$$

Recent investigations indicate that an increase in the degree of light adaptation causes a decrease in the slope of recovery of the rod adaptation function and a displacement of the function to the right on the time axis. Over a wide range, these changes occur to the same extent irrespective of whether the increase of the degree of light adaptation is produced by raising the intensity or by prolonging the exposure. Within these limits the Bunsen-Roscoe reciprocity law applies to the intensity and duration of pre-exposure. Over a still wider range, dark adaptation follows the same course subsequent to a brief exposure to a bright light as it does after prolonged exposure to a dim light, provided the degree of light adaptation is the same in both instances as indicated by identical initial thresholds of dark adaptation.

4. The size of the area of retinal test. Obviously the number of rods or cones or both which may be affected by the retinal stimulating light will depend on the area.

5. The retinal location. At the fovea, cones only will be tested: peripherally (say at 20 degrees) rods chiefly.

6. The color of the light used for the determination of threshold levels. In the extreme red portion of the visible spectrum it is to be noted that the final thresholds of the rods and cones are about the same and the rate of recovery is very rapid. Hence cone adaptation only will be elicited when the course of dark adaptation is investigated with the use of red light. On the other hand, if blue light is used, after the initial very rapid cone adaptation, the threshold should continue to decrease because of the low level to which the responses of the rods finally sink. A series of intermediate results will be obtained for various colored lights between the extreme blue and the extreme red end of the spectrum.

7. The duration of the exposure to the light used during the course of dark adaptation (intermittent exposure).

8. The size of the pupil. In the determination of standards and in clinical investigation the size of pupil is highly desirable, if not absolutely necessary, to a correct evaluation of dark adaptation levels. It is customary to reduce all values to those which would obtain with a constant pupillary diameter of 5 mm. However, in the case of measurements of pilots and night fliers and in certain types of aeromedical investigations, I am of the opinion that data on dark adaptation should be taken with both eyes of the subject exposed (hence having no regard for ocular dominance or relationships of accommodation and convergence, binocular single vision and other factors) and with the pupils as they are, irrespective of their size or photostatic activity, for the reason that the data should be obtained on the pilot under his own unhampered responses to the environmental conditions that are imposed. These environmental conditions should simulate actual flying conditions as closely as possible.

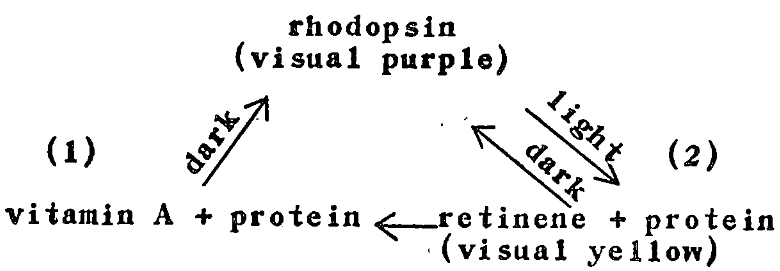
VISUAL ADAPTATION STANDARDS

Before it is possible to test correctly the effects of dietary deficiencies on dark adaptation or to presume to consider certain experimental data as evidence of either subclinical or frank manifestations of vitamin A deficiency, it is necessary to ascertain the normal distribution of the characteristics of dark adaptation. Hecht and Mandelbaum (**5**) surveyed 110 persons, Wald, 1941, (**18**), investigated day-to-day variability and I tested a large group of pilots in a commercial air line, as well as a considerable number of school children and inductees into the military forces. All of us agree on the values of the thresholds of cone and rod adaptation as influenced by the various factors rehearsed in the paragraphs devoted to criteria for precise measurements. In general, there is a spread of 0.5 log unit among the 80 per cent of those who are considered normal subjects. With care in technic, attention to diet and a consideration of the blood sugar level, it is possible to obtain day-to-day determinations on the same person within 0.1 to 0.2 log unit. Age has an influence on dark adaptation. The cone threshold slowly rises with age. In the fifteen to twenty year group there is a skew in the distribution of rod thresholds to the left; in the twenty-one to twenty-five, twenty-six to thirty-nine and forty to sixty-five year groups, there is a definite skew to the right which increases with age. All of this indicates what some of us have found out from experience, namely that the youngsters, who are neophytes in aviation and are less than twenty years of age, as a group have better dark adaptation levels for both rods and cones than the experienced pilot of the late thirties and early forties.

The chances are high that the average person when tested will give a dark adaptation curve which will fall in the 80 per cent band of the spread from individuals with superior night vision to those whose levels are high and who would be considered definitely as unsatisfactory for duties involving good night vision. As a matter of fact, statistical studies based on careful tests, adequate controls and correct standards indicate that not more than 2 per cent of the population of the United States show abnormally high or pathological levels of dark adaptation. However, the subclinical conditions of dietary vitamin deficiency are much more frequent than frank deficiency and are worthy of much further clinical investigation. All of this, however, does not furnish any excuse for everything from corn medicine to cough drops being vitaminized indiscriminately in these United States of America. In other parts of the world and in the care of the military forces, some inclusion of vitamins as accessory foods and protective agencies is highly desirable.

CHEMISTRY OF VISUAL ADAPTATION

To anticipate somewhat the presentation concerning avitaminosis A, it was discovered some years ago that, for a proper understanding of the chemistry of vision, one significant consideration is the almost parallel behavior of rod and cone thresholds during the periods of deficiency and those of supplementary adequate diets given during the periods of recovery. This fact must mean that, just as vitamin A enters into the chemical cycle of rod vision because of its association with visual purple (rhodopsin), so it also enters into the chemical cycle of cone vision and that the cone sensitive substance [Wald, 1937, (**17**); Chase, 1938, (**3**)]—iodopsin or visual violet—is probably also a conjugated protein like rhodopsin and porphyropsin. There is a visual photochemical cycle involving one or another of the three known photosensitive substances, which are in dynamic relation with their photoproducts (protein, retinene and vitamin A). The photoproducts, in turn, are the precursors from which the photosensitive substances are formed again. Wald has summarized the direct chemical information concerning dark adaptation now available in the following schema:



CLINICAL CONDITIONS AND CONSIDERATIONS

From a consideration of the biophysical and physiological measurements and responses of the rods and cones in visual adaptation, it is apparent that there are three fundamental elements which may exert an influence on dark adaptation. These factors are:

1. Pigment or pigments and the conditions that may affect the photochemical reactions and changes;
2. Metabolism and nutritional state, both of the body and of the retina as a localized site of pigment and photochemical reaction;
3. Neural and cerebral responses, which are exhibited so strikingly in anoxia and certain aeromedical problems. Without doubt, these neural and cerebral factors enter into many clinical syndromes. The retina is closely related to the brain—embryologically, morphologically and physiologically. According to Krause (**7**): "The metabolism of the retina is similar to that of the brain, and not of other tissues. This is to be expected since the retina is anatomically a part of the brain. Weinstein (**19**) reported that in the retina and brain the oxygen consumption and carbon dioxide production aerobically and anaerobically are similar."

DIETARY AVITAMINOSIS A AND DARK ADAPTATION

The relations between vitamin A and dark adaptation depend on three known facts. In the first place, as has been shown by Wald, 1935, (**16**) and again later by Hecht, 1940, (**4**) vitamin A is a constituent part of the photosensitive pigment (or pigments perhaps) of the rods and probably also of the cones. Secondly, it is an established clinical fact that many persons, whose dark adaptation thresholds are abnormal, are improved in their ability to see in the dark through the administration of vitamin A. Thirdly, night blindness or impaired night vision can be produced in some instances by feeding the subjects a diet deficient in vitamin A. All relevant investigations are based on one or more of these facts. If no organic disease of the eye, such as retinitis pigmentosa, is present, measurements of dark adaptation, when made under critically standardized and controlled conditions, can be used as aids in the determination of avitaminosis A. This condition may be produced by a lack of vitamin in the diet, by a functional disarrangement of the transfer of the vitamin from the diet to the retina, by a lack of reserves in the liver or by unavailability of reserves.

A major portion, to say the least, of the researches which were published concerning vitamin A deficiency and dark adaptation from 1930 to 1940 laid stress on (1) the similarity of effects on cone and rod functions in vitamin A deficiency, (2) the relative ease with which dietary vitamin A deficiency could be produced and (3) the inference, if not the direct statement, that there was a high incidence of deficiency: for example Jeans and Zentmire, 1934-1936, (**6**) who reported a disturbance in 21 per cent of a group of 213 children in a children's hospital in Iowa. More recent investigations have shown that dietary vitamin A deficiency is not readily induced in healthy and nutritionally stable individuals [Steffens, Bair and Sheard, 1940 (**14**); Brenner and Roberts, 1943, (**1**) and others.] If avitaminosis A, as judged by changes in dark adaptation thresholds, is induced it is likely to occur in a few weeks of subsistence on a diet deficient in the vitamin. The period of recovery, even with the oral administration of large doses of vitamin A, is protracted and may involve several months' time.

Apparently vitamin A deficiency is not common in this country. Normal subjects placed on a vitamin A deficient diet in general appear to have sufficient stores in the liver to maintain sufficient vitamin A in the blood and tissues, such as the retina, for many months. Theoretical calculations on the average content of vitamin A in the human liver and the assumption that the rate of use is approximately 2,000 U.S.P. units per day indicate that it would take from one to two years to lose its entire store of vitamin A even if there were no vitamin A present in the diet. Lewis and Haig (**9**) tested a large group of children in New York City. When one considers that many of these children came from very poor homes and that, furthermore, many of them had been suffering from a febrile disease, the conclusion seems warranted that "vitamin A deficiency, on the basis of dark adaptation, is an uncommon disorder in children in New York City." Furthermore, Steven and Wald, 1941, (**15**) made measurements on several hundred persons in Newfoundland and Labrador, areas from which epidemic night blindness had been reported. They employed what is known as a vitamin A labile threshold as a criterion of deficiency—a threshold such that there was a very definite improvement (about twofold) within two weeks of a normal diet supplemented with 15,000 units of vitamin A daily. Vitamin A labile thresholds were found in about 10 per cent and clinical night blindness was found in at most 3 per cent of the subjects. No xerophthalmia or keratomalacia was encountered. Hence there is little evidence to show that any considerable part of the population is suffering from a vitamin A deficiency such as has been reported in the literature from time to time. Clinically, my colleagues and I can cite from our investigations various conditions of dietary avitaminosis A, follicular hyperkeratosis and pityriasis rubra pilaris (**2**), and cirrhosis of the liver in which the dark adaptation thresholds have been found to be abnormal and which have either been restored to normal levels or materially benefited through the administration of vitamin A. These are types of disease in which visual dysadaptation is likely to occur.

EFFECTS OF ANOXIA ON DARK ADAPTATION

During the war of 1914-1918 Wilmer and Berens (**20**) made the first systematic studies on the effects of lack of oxygen on the aptitude of pilots at high altitudes. Standard tests were given to a large number of normal and of defective subjects in a low pressure chamber as well as oxygen deprivation with a rebreathing apparatus. A considerable part of the more recent literature has appeared in foreign periodicals but, with few exceptions, the work has not been controlled carefully. In general, however, the investigations showed significant effects of deprivation of oxygen on many visual functions.

Nervous tissue has been shown to be particularly sensitive to a deficit of oxygen. Consequently it is not surprising that investigation of certain functions which involve the retina has revealed that these also manifest extensive changes on exposure of the subject to low oxygen tension. Certain visual characteristics, such as sensitivity to light, are affected more easily than others, such as visual acuity or size of the visual field. It is very difficult (and perhaps impossible) to determine to what extent the effects of anoxia on vision are due to alterations in the central nervous system and to what degree the organ itself is affected. There is an increasing amount of evidence to indicate that the neural components of the retina and of the brain are more extensively involved than was supposed originally, even in such characteristics as sensitivity to light and visual acuity.

In a general way it is known that moderate degrees of lack of oxygen cause a general darkening and narrowing of the visual field and then a blurring of form or a decrease of acuity. With increased severity of anoxia there is frequently a cessation of all visual sensations just previous to loss of consciousness. A general dimming or darkening of the visual field often is reported by pilots while flying at considerable heights (for example, 17,000 feet [5,200 meters] and above) without oxygen.

Investigation indicates definitely that measurements of the thresholds of light sensitivity offer one of the most delicate methods for obtaining information regarding the initial as well as the advanced effects of anoxia. Subsequent to the administration of low oxygen mixtures (8 to 12 per cent of oxygen) there is a decrease of retinal sensitivity which varies somewhat in different subjects, with a restoration to normal levels through the administration of oxygen. Since such changes also take place in thoroughly dark-adapted subjects, destruction of visual pigments or a delay in their regeneration cannot be involved in all probability. Furthermore, the return to normal retinal sensitivity under the administration of oxygen is too rapid to be accounted for by regeneration of rhodopsin.

The results of the work of various groups of investigators, particularly McFarland and Forbes (**10**), and my colleagues and me, emphasize (1) the effects of lack of oxygen on both the cone and rod thresholds of dark adaptation after sufficient lapse of time (twenty-five to thirty minutes) to ensure photochemical and pigmentary equilibrium; (2) the beneficial effects of oxygen on the dark adaptation thresholds of certain subjects at relatively low altitudes (for example, 5,000 feet [1,500 meters]) and under untoward environmental circumstances or fatigue, and (3) the general stabilizing action of oxygen.

The various experimental results concerning the effects of anoxia, metabolism and respiratory rates lend support to the thesis that the visual threshold offers a very practical quantitative index of physiological imbalance. It is more sensitive and reliable for this purpose than any subjective awareness of distress or sensory change. It has an advantage over certain other types of physiological measurement, for it provides an index of the change in the central nervous system itself—usually the first to fail in physiological stress.

PRACTICAL POINTS AND SUGGESTIONS CONCERNING NIGHT VISION

Complete darkness is the best preparation for night vision. It is essential to protect the eyes from light before attempting night secing and also while so engaged. If one cannot remain in darkness, keep the lights as low as possible and do not look straight at them. If it is necessary to look at any lighted object, do it as quickly as possible. These statements of caution are applicable also to illumination of airplane instrument boards and cockpits. Even very low illumination with the correct color of painted dials cuts down the distance at which objects may be discerned as much as 50 per cent.

It is possible to become dark-adapted or to maintain dark adaptation even though working in a fairly bright light. A patch worn over one eye (the pirate's patch) will keep the covered eye in a state of readiness and adaptation for night vision. Of course vision with one eye is not as accurate as two-eyed vision, especially in judging distances of nearby objects. One may work in red light or wear red goggles or even highly absorptive glasses and become well dark-adapted.

It is necessary to look a little to one side or "out of the corner of the eye" to see best on a very dark night. Learn not to look straight ahead in the direction from which light is sensed; it will disappear (that is, not be adequate to produce visual sensation) in direct vision. Do not look steadily in any direction. Scan the landscape or sky; do not sweep over it. Night eyes are slow in responding.

Vision at night is affected markedly by the contrast between the object and the background. An airplane may be visible if one looks up at it against the night sky, but invisible if looked down upon against a dark background.

To notice small differences in contrast it is essential to have clear, clean vision. Windshields must be kept clean and free of scratches or fog. These tend to scatter light in all directions and to reduce contrast. "Careless night fighters have been known to tolerate enough dirt on their windshields to double the time it takes to see a plane moving along nearby." For the same reason it is important to keep the lights as dim as possible on the observer's side of the windshield. Any light on the operator's side reduces the contrast because stray light spreads over the whole glass and reflects into the eyes. That is why one pushes up as close as possible to a window when trying to look out at night.

There has been much talk about the effects of shortage of vitamins A and C on the ability to see at night. The incidence of impairment of night vision because of vitamin deficiency is low; probably about 2 per cent. Extra vitamins do not improve night vision if such vision is already normal and the intake of vitamins is adequate. Those in the armed forces, especially on overseas duty, must be supplied with extra vitamins.

Night vision is affected by fatigue. Anything that reduces the physical well-being has a greater effect on night vision than on day vision. Investigation has shown that hang-overs, colds and other slight illnesses, or excessive fatigue may double or even triple the amount of light needed to see an object.

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MODERN PLASTICS

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