THE BRITISH JOURNAL

OF

OPHTHALMOLOGY

NOVEMBER, 1946

COMMUNICATIONS

THE MIDDLE EAST ADAPTOMETER*

BY

W. H. WILSON, M.A., M.D.(Oxon)

EMERITUS PROFESSOR OF PHYSIOLOGY,
FACULTY OF MEDICINE, CAIRO

A LARGE number of instruments for the investigation of dark adaptation or the detection of night blindness have been described by different observers and are in use. It is not the object of this note to add unnecessarily to the number.

The adaptometer described in this communication was devised at the request of the Army Medical Service in the Middle East in 1941 partly because no such apparatus was available at the time or could be copied from published descriptions as the necessary materials were not available in Egypt, and partly to meet certain specified conditions. I have to thank Brigadier C. W. Graham, at the time Ophthalmic Consultant, for his help and advice.

The requirements were that the apparatus should be light and portable, that it could be used in a tent or generally where no dark room was available, that it should be sufficiently simple in construction and working to ensure that reliable results could be obtained by Medical Officers with no special training or scientific knowledge of the subject, and lastly that it could be constructed reasonably cheaply from materials obtainable locally.

The primary purpose of the apparatus was to test the limits of dark adaptation in the considerable number of men complaining of night blindness and later to determine whether the night vision

* Received for publication, June 21, 1946.

of men on special duties, such as night driving, was sufficiently good.

The adaptometer, shown in Fig. 1, consists of three parts:—the observation (testing) chamber A, the lantern B, and attached in front of B, a device for varying the intensity of the illumination, the reducer, e.

DESCRIPTION. Fig. 1. The apparatus resembles in many respects that described by A. M. Thomson and others, which was used by them in the study of dark adaptation as an index of an adequate vitamin A in-take. The external dimensions and construction, the use of an opal glass at a distance of 33 cms. from the eyes of the subject, and the test objects used, are taken from the description of the Rowatt Institute apparatus, as is the use of a 6-volt lamp

FIG. 1.—Side view section of Adaptometer.

A. Testing chamber; B. Lantern; a. Visor; b. Slide carrier; c. c. Slides; d. Opal glass screen; e. Reducer; f. Lamp-holder, 6 watt lamp; g. Volt-meter; h. Variable resistance; k. Switch battery connection; m. Base board; L. L. Support and rack for adjusting height; N. Black curtains for excluding light.

with a 5-volt current. The method of assessment of dark adaptation, the procedure adopted, and the calibration of the instrument, differ.

The *observation chamber* is a wooden box 55 cms. in length, 22 cms. in width, and 15 cms. in height (external measurements). At one end is a visor (a) carefully shaped and the edge well padded to fit the upper part of the face and bridge of nose of the subject with a corresponding aperture in the end of the chamber. At this end is a support (see Fig. 1) carrying curtains of black material which hang on either side of the subject's head and can be, if necessary, pinned under his chin to exclude extraneous light if the visor is not a good fit.

If the adaptometer is to be used in a lighted room the form of the visor is of great importance. The form I have found most satisfactory is in shape similar to that of the visor made in bent wood of the old fashioned hand stereoscope. It should be made of bent metal perforated at the edge for attachment of the resilient packing; this is made of either thin $\frac{1}{4}$ in. rubber tubing or cotton wadding covered loosely with black velvet or plush. The dimensions are from right to left covering both eyes $5\frac{1}{2}$ in., depth at sides 3 in., between frontal edge and bridge of nose contact $1\frac{1}{2}$ in., depth at bridge of nose 1 in.

At the other end of the box is a centrally placed aperture through which light is admitted from the opal glass diffuser plate of the reducer. This plate is in close contact with the end of the chamber, when the lantern is in position for a test.

At 25 cms. from the lantern end is an opal glass screen (*d*) the flashed opal surface being in front. The free surface of the screen within its mounting is 10 cms. square. It is about 33 cms. from the subject's eyes.

Through a slot in the roof of the box immediately in front of the screen (*d*) a lantern-slide carrier (*b*) holding two slides (*c*) and (*c*) can be introduced. The clear glass slides carry figures in black such as a capital *E* or a numeral, the figures being 4 cms. high. The illuminated area of the slide visible to the subject is 7 cms. square. The slide-carrier can be taken out and reversed or inverted to show a new figure. A subject can thus be tested with 4 different images.

The board forming the floor of chamber (*A*) is extended backwards to carry the lantern (*B*) and is hinged to a base board (*m*) 1 metre in length, so that the visor can be adjusted by the support and rack (*L*) to the sitting height of the subject.

With some of the instruments was issued a small table 90 cms. long and sufficiently wide to allow the subject to rest his forearms, on either side of the chamber. The adaptometer can, of course, be used on any table of such a width so that the subject can sit at the visor end and the observer at the lantern end.

The Lantern B, in Fig. 1 (See also Fig. 4). This is a wooden box 25 cms. in length and 14 cms. in width and height. It contains a lamp holder carrying a 6-watt lamp. The right side opens on hinges to permit of adjustment of the lamp. The lamp holder (*f*) (Fig. 1) is held by guides *D* (Fig 4) between which it can be moved along a millimetre scale for the exact adjustment of the distance of the lamp filament from the front surface of the opal glass diffuser plate of the reducer. (For the lamp holder *f* see (Fig. 1) and *A* (Fig. 4)).

To the front of the lantern case is attached the light reducing device *e* (Fig. 1) and to the back an instrument panel at a convenient inclination. On this are mounted a voltmeter *g*, a variable resistance *h*, and a switch *i* (Fig. 1). The voltmeter is connected across the lamp terminals. On the base board is a plug *k* (Fig. 1) through which the current for a 6-volt accumulator can be plugged in.

Wiring.—A connection is made from one pole of the plug (*k*) to the moving arm of the rheostat (*h*). From the terminal of (*h*) the current passes to one of the terminals of the lamp voltmeter. The other pole of the plug is connected to the switch (*i*) from which the connection is made to the other lamp terminal (Fig. 1).

*The Reducer (Figs. 2 and 3).—*The variation of the intensity of the illumination is effected in two ways :—

(i) The full aperture being 20 mms. diaphragms of 5, 2 and 1 mm. diameter are provided (Figs. 2 and 3B).

(ii) The light passes through two polaroid discs (*C* and *D* in Fig. 2). *D* is fixed. *C* can be turned through an angle of 90° , so that starting at zero with the axis of the two polaroids at right angles, any desired percentage increase of the light can be obtained.

Description.—The reducer (made of metal or vulcanite) is built

FIG. 2.—Section of Light Reducing Device.

1. 2. 3. 4. Component sections from before backwards; A. Opal glass diffuser plate; B. Diaphragm quadrant; C. Movable polaroid disc; D. Fixed polaroid disc; E. Seating of polaroid C; I. Indicator arm of same; H. Extension upwards of sec. I to carry reducer scale; F. Seating of polaroid D; G. Fixing screw of same.

FIG. 3.—Back view of Reducer as attached to front of Lantern.

Lettering the same as in Fig. 2.

B. Diaphragm quadrant; B. Indicator arm of same; S. Scale; D. Fixed polaroid disc in seating F and fixing screw G; E. Mounting of movable polaroid with indicator arm I; H. H. Scale showing percentage decrease in illumination.

FIG. 4.—Section through Lantern at level of Lamp holder.

A. Lamp holder; B. 6 watt lamp; C. C. Pointer traversing, millimetre scale; D. D. Guides between which lamp holder slide; E. Hinged side door for adjustment of lamp position.

up of four sections (1, 2, 3 and 4 in Fig. 2) 10 cms. square and 0.5 cm. thick.

Section 1.—Inlaid on the front surface of this is an opal glass plate A flashed on the front surface (the “diffuser”). The opal plate covers a centrally placed aperture 20 mms. in diameter.

This section is extended upwards to carry the scale showing the percentage change in the intensity of the light produced by the turning of the polaroid disc C.

Footnote.—To avoid considerable error, especial care must be taken in regard to three different factors.

(i) The zero point of the lamp scale. This is the point at which the lamp filament and the front surface of the diffuser would be in contact. It is determined after assembly of the reducer and attachment to the lantern by measuring with micrometer calipers the distance of the front of the diffuser from the lamp filament with the lamp in its most forward position. At its base the lamp holder carries a pointer which traverses the millimetre scale.

For example, it was found in one apparatus by careful measurement that the lamp filament was 28 mm. distance from the diffuser surface; the millimetre scale was then fixed with the pointer at 28 mm., on the scale, the zero point being thus correctly placed. Any measured point on the scale to which the lamp is moved will then give the distance of the filament from the diffusing surface.

(ii) It is essential that the diaphragm aperture shall be exact. In the case of the 1 and 2 mm. diaphragm the diameters must be verified under the low power of a microscope with the eye piece micrometer, and any error corrected.

(iii) The two polaroid discs must be in correct position. This is best done by superimposing the two discs before mounting and turning to the position at which least light passes. A line in a corresponding position on the periphery of each is made in ink. When cementing in, the line on one must correspond to the centre line of the indicator arm of seating E and on the other to the fixing screw G of seating F. The exact adjustment is made, as described above, after assembly.

Note.—I have to thank Major C. Cockburn for helping me to test out the apparatus on a number of subjects at No. 15 General Hospital and later for an account of the results he obtained at No. 6 General Hospital at Tel el Kebir: and Major H. H. Aitchison for his report on the use of the adaptometer at No. 9 Hospital.

I also have to thank Professor Rosgyll Ayres of the Physics Dept. of the Fuad I University Cairo for the information given regarding the various physical light units.

Section 2 holds the diaphragm quadrant *B*, shown in Fig 3, with its aperture of 20, 5, 2 and 1 mm. Fig 3 shows the form of the quadrant with the 5 mm. diaphragm *in situ* and its indicator scale *S* which is attached to Section 1.

Section 3.—Inset in this section is the seating *E* of the polaroid disc *C*. The seating is circular and projecting from it is the arm *E*, by which *C* is turned which serves as the indicator of the percentage change in the illumination. The seating is shaded in Fig. 2.

Section 4.—Inset in this section is the seating *F* of the polaroid disc *D*. The seating can be turned about 10° right or left and is fixed, when correctly adjusted to the axis of polaroid *C* by a screw *G*. This passes through a slot in the seating *F* which is sufficiently long to give the required range of adjustment. It is intended as a fine adjustment to correct any error which may be made when cementing the discs in their seating. The two polaroids are adjusted so that at zero on the scale their axes are at right angles and no light except a deep red passes, while at 100 on the scale their axes are parallel and the maximum of light is transmitted.

The four sections of the reducer are held together by screws and the whole is attached to the front of the lantern by wood screws.

When prepared for an observation the lantern, which runs between guides on the base board, is pushed into close contact with the back of the observation chamber so that the diffuser plate of opal glass is flush with the outer back surface; the distance of the diffuser from the opal screen of the chamber should then be exactly 25 cms.

When calibrating the adaptometer the distance (from the zero point on the millimetre scale to which the lamp must be moved) is found at which the illumination from the diffuser corresponds to 1 c.p. and $\frac{1}{4}$ c.p. respectively.

The above details are given to assist instrument makers or others who may wish to construct the adaptometer.

Calibration.—That is the determination of the intensity of the light visible to the subject as a background to the figure he has to distinguish in fractions of a ft. candle.

The primary measurement of the light emission from the diffuser has been made with a sensitive selenium-coated front-wall photo-electric cell giving 3 micro-amps per ft. c. of incident light with the micro-ammeter employed. The light value of the cell was determined with a Hefner lamp giving 0.9 ft. c. at 1 foot distance, in the Physics Department of the Cairo University.

The calibration must of course be carried out for each apparatus and should, where possible, be repeated periodically. It is carried out as follows :—

The photo-electric cell is fixed with the sensitive surface exactly 25 mm. from the opal surface of the diffuser plate, the full diaphragm aperture of 20 mm. being used and the polaroid percentage indicator at 100 on the scale.

The battery current is then switched on and the voltage adjusted by the rheostat to 5 volts.

The lamp holder is then moved forward until the ammeter shows 12 milli-amps. The position of the lamp as indicated by the millimetre scale will then correspond to a light intensity of 4 ft. c. at distance of 25 mm. from the diffuser.

At double this distance the intensity will equal 1 c.p. at four times $\frac{1}{4}$ c.p. The 4 c.p. position is verified 5 times and the mean, if any discrepancy occurs, taken.

The measurements on the millimetre scale being found at which the intensity is 1 and $\frac{1}{4}$ c.p. respectively are recorded on a card which is issued with each apparatus, as these are working intensities of the light source at which observations will be made. The card is permanently attached to the lantern casing.

It is evident that the opal screen of the chamber being 25 cms. from the diffuser and the light emitted by the latter being measured at 25 mm., the light incident on the screen with the lamp in the 1 c.p. position will be $1/100$ c.p. or in the $\frac{1}{4}$ c.p. $1/400$.

A correction has to be made in addition, as the opal glass screen does not emit the full amount of the incident light.

For example, in the last apparatus calibrated, the opal glass used was found to transmit $7/10$ of the incident light. The illumination of the background visible to the subject will therefore be diminished to that extent.

The factors required for the estimation of the luminosity of the background are:—

(a) The light emission from the opal screen, with the full aperture.

(b) The diaphragm size used (5, 2 or 1 mm.).

(c) The candle-power used (1 or $\frac{1}{4}$ c.p.) and

(d) The percentage reduction on the polaroid scale.

Thus with the lamp in the 1 c.p. position the 5, 2 and 1 mm. diaphragms reduce the light to $1/16$, $1/100$ and $1/400$ of the maximum respectively, and with the lamp in the $\frac{1}{4}$ c.p. position to $\frac{1}{4}$ of these figures. It being possible to reduce the illumination further to from 90 to 10 per cent. with the use of the polaroid reducer.

A table of values is issued with each apparatus, calculated from the calibration figures, from which the readings obtained can be converted to fractions of a ft. c. A copy of this should be kept inside the lantern.

Two 6-watt (motor-car side lamp) bulbs are provided with each adaptometer, the 1 c.p. and $\frac{1}{4}$ c.p. position for each being given

on the card attached to the apparatus. The lamps have been aged before issue by 100 hours' continuous run.

INSTRUCTIONS FOR THE USE OF THE "ADAPTOMETER."

1. Care must be taken that the voltmeter shows 5 volts. If it shows a higher voltage, the rheostat knob must be turned clockwise.

If 5 volts cannot be obtained, the battery requires recharging.

2. The lamp must be fixed at the exact point on the lamp scale stated to give 1 or $\frac{1}{4}$ c.p. as the case may be.

3. The lantern must be pushed well home so that the diffuser plate is in contact with the observer's end of the observation chamber.

4. *Position of the subject.*—The subject should be seated with his feet together and his knees between the legs of the table so that his chest touches the end of the apparatus, his forearm and hands placed on the table on either side of the base board of the apparatus. The observation chamber must be raised so that it is adjusted to the patient's sitting height, so that he can press his face against the visor without stooping. Unless this is done there may be a leak of light between the visor and the face below the eyes and around the nose. The subject should be sitting as upright as possible, leaning forward with the visor at the normal level of his eyes.

5. In making an observation on the light adapted eyes, the 1 c.p. illumination should be used with the 20 mm. diaphragm. If this is found to be too high a degree of illumination, the diaphragm must be changed to the 5 mm.

6. *Procedure in testing for dark adaptation.*—The $\frac{1}{4}$ c.p. position of the lamp and 1 mm. diaphragm are used. If, with the reducer arm at 100, the subject still cannot distinguish the figure, the 2 mm. diaphragm must be put in place of the 1 mm. If this is still insufficient, the lamp must be shifted to the 1 c.p. position.

7. When making an observation, the reducer arm is placed at zero scale, the light being turned off, the subject is asked if he can see anything. If he can, there is a leak, which is probably at the visor, if it is not adjusted correctly to the subject's sitting height.

If not, and the room is brightly lighted, it is probably at the junction of the lantern and chamber, or at the slot through which the lantern slide carrier enters. As a precaution, a piece of black cloth should be draped over these two places.

8. If, as should be the case, the subject sees nothing, the reducer arm is advanced to twenty on the scale, the light switched on, and the arm advanced slowly 10 divisions at a time until the subject states that he sees a faint light, the scale reading is noted

and the procedure continued until a point is reached at which the subject can distinguish the form of the test figure. The reading at that point is noted. The result is confirmed by changing the test figure and repeating the procedure.

9. The following procedure is recommended if measuring the adaptation to darkness of a number of individuals.

(a) The name, age and other details of each subject are entered upon a card.

(b) The subjects are then called one by one and the retinal sensitivity of the light adapted eyes tested, and the result recorded on the card. The purpose of this is mainly to instruct the subject as to how he should sit at the apparatus, and the procedure generally, so that after dark adaptation when he is brought to the apparatus blindfold he will know what to do. The number of steps the chamber must be raised to suit the height of the subject's eyes should be noted.

As each subject is finished, he is told to sit on the verandah or in front of an open window facing the light. He should not sit in direct sunlight.

After twenty minutes, the subjects are called in one by one at intervals of about 3 minutes, in order of their examination. The subject is then either placed in the dark room (if available) or is fitted by the observer with a black eye-mask and sent to wait in any place which is not brilliantly lighted. If the eye masks completely exclude all light, he may sit on the verandah with his back to the light.

(c) After thirty minutes, the first subject is called in, a black eye-mask having been placed over his eyes before leaving the dark room. He is guided to the chair, and then seated in the correct position, told to keep the eyes closed until told to open them. The observer then removes the eye-mask and tells the subject to press his face against the visor, and then open his eyes.

The test is then carried out as described above.

The following shows the type of record which should be kept for each subject:—

- (a) Age of subject.
- (b) Does subject think he has good or bad night vision?
- (c) Is there any visual defect?
- (d) Threshold of light perception after 30 mt. in dark.
- (e) The same for form perception.
- (f) Date of test.
- (g) Date and result of any previous test.

In view of the fact that the general purpose of the apparatus is to test men for night blindness or defective dark adaptation by determining the threshold sensitivity of the retina to light after a

period of thirty minutes in the darkness, the preliminary twenty minutes period of bleaching may be omitted, and the subjects, after the retinal sensitivity of the light-adapted eye has been tested (procedure B) may be admitted at once to the dark room.

Discussion

It must be clearly understood that the method of observation is designed to determine the capacity of an individual to distinguish an object after dark, that is the threshold lighting of the background against which the outline of the object can be seen, and, if the form is one the subject is familiar with, the recognition of the nature of the object.

The threshold of light perception is slightly lower; there is, in fact, a noticeable gap between the point at which the subject first perceives light and his recognition of form.

The light threshold and the threshold for the perception of form in a large number of individuals do not run parallel. The probable cause of this is that in the recognition of form an intellectual process is involved.

There are certainly other factors concerned in form recognition than in the simple perception of light; if, however, the subject be instructed (in section 8 of the procedure described) to state

- (a) when he sees the faintest sign of light and
- (b) when he can recognise the form of the test figure, a double purpose is served first whether the dark adapted eyes are less sensitive to light than the normal and secondly whether the subject has sufficiently good night vision for his duties.

In the R.A.F. medical examination the threshold of "form perception" is the basis of the night vision test.

Air Commodore Keith Lyle has been good enough to give me the results obtained with the adaptometer in tests of night vision in 1,000 air crew candidates carried out by the R.A.F. Medical Board at Heliopolis, and of 44 French candidates examined at the request of the French Air Force and Naval medical boards at Algiers. Air Commodore Lyle states that the simplicity of this adaptometer, and the fact that only one man is examined at a time has made it of great value when dealing with men who do not speak English, or with men who are stupid or non-co-operative. Furthermore, with a large dark room, a considerable number of men may be examined at one sitting. The standard threshold adopted for a "pass" for air crew service was 0.021 m.f.c. or less.

The procedure used was to test simply the threshold of the "form perception" after 30 mts. of dark adaptation, which was carried out by keeping the candidates in a completely dark room for this period.

In a first trial the point was noticed at which the subject could describe correctly a test figure, *e.g.*, an "E." A second trial was then given immediately after the first with a different figure, and the result recorded. Thresholds observed in one thousand subjects are as follows:—

With a "pass" threshold of $\cdot 0025$ m.f.c. Mean result first trial $\cdot 00224$; second trial $\cdot 00185$. Failures—first trial 11.6 per cent.; second trial 4.4 per cent. Pass threshold $\cdot 0021$. Failures first trial 30 per cent.; second trial 12 per cent.

The lowest threshold observed for form perception was $\cdot 00103$; the highest $\cdot 0086$.

The trials were given at the same sitting, the second immediately after the first. It is obvious from the results that at least two trials are essential. The improvement in the second is doubtless due to the subject's familiarity with the procedure.

The essential visual quality for air crews is good form perception at night; for this reason the threshold of light perception was not examined.

The results in 44 French candidates tested at Algiers with a $\cdot 0021$ threshold were as follows:—

Pass 91 per cent.; failures 9 per cent.

The mean figure for subjects registering $\cdot 0021$ m.f.c. or less was $\cdot 00151$, the lowest figure $\cdot 00103$.

A comparison was made of the results observed with the apparatus described, the Watson adaptometer and the Livingston rotating hexagon.

Tests of 24 subjects with the first type of adaptometer showed 24 passes; with the second (threshold less than 7.5 micro-Lamberts) 18 passes, 6 failures and with the third, 21 passes and 3 failures.

From the results obtained later from 100 normal subjects, Air Commodore Lyle concludes that subjects who pass with the adaptometer described in this paper, would usually pass with the Livingston rotating hexagon.

The determination of the minimum threshold for light in the dark adapted eye is not of the same importance for the purpose for which the adaptometer is designed, namely the detection of night-blindness and its degree, or the suitability of an individual for duties in which good night vision is required.

The apparatus could, with necessary modification in procedure, be used for measuring the rate of adaptation and the plotting of the relative curve.

The number of subjects that could be examined in an hour would, however, be very limited, possibly two; whereas the simple testing of form perception can be easily made on 15 or even more subjects in an hour with proper organisation.

The procedure in the majority of dark-adaptation tests is to "bleach" the retina by exposure of the eyes to a strong light of known candle-power, *e.g.*, a 50 c.p. lamp, for a definite time, *e.g.*, 3 minutes, immediately before the period for dark adaptation begins.

This seems to be essential if the rate of adaptation is to be determined, but is unnecessary if the final threshold only is to be measured as this appears to be unaffected by the extent of the preliminary bleaching.

In the procedure described, the eyes are exposed to the light on a shaded verandah which, on a bright day in Egypt, often corresponds to the equivalent of 900 ft. c. and the test is therefore carried out on the completely light-adapted retina.

If the accommodation is limited and efficient dark goggles (black or deep red) are available, the 30 min. dark adaptation may be carried out without the men leaving the verandah until they are called in for testing.

A fixation point of red light is not used partly to avoid complication of the apparatus and partly because the area of the retina covered by the image of the 7 cm. square is that which is normally used in observation of the foreground. This area is 5 mm. square and the diagonal extends for about 3 mm. from the edge of the fovea (an angular distance of 9°) into the extra-foveal region of the retina. Apart from this, subjects may be encouraged when the test begins to move their eyes, to look about them, and under these conditions peripheral regions of the retina much further from the fovea will be exposed to any light emanating from the opal screen.

An objection to the use of a fixation point, which seems to me to be of importance which I have not seen discussed in the literature, is this:—the fixation point is in some instruments not very distant from the point of normal near vision. This being so, accommodation with convergence of the visual axes must occur and must undoubtedly be accompanied by reflex contraction of the pupil with a corresponding diminution of the light reaching the retina.

When the procedure to be used was drawn up, the question arose as to whether a mydriatic should be used in view of the fact that the size of the pupil in the dark adapted eye varies in different individuals and under different conditions. (See Phillips, *Proc. Roy. Soc.* 127, 405, 1939 and Sloan, *Arch. Ophth.* 21, 915, 1939). It was decided first that a mydriatic should be excluded by the fact that most of the men were not hospital patients and would be incapacitated for that day. Secondly because the object of the test was not to determine the threshold of the retina with the full dilated pupil but the subject's normal vision with the dark adapted retina.

The unit adopted for the measurement of the light visible to the eyes of the subject is the foot candle or milli-foot candle. This seems to me preferable to the physical units (micro-lux or micro-micro-lambert or their corresponding log-units), used by some investigators, or the purely arbitrary units used by others.

As pointed out by Mandelbaum (*Arch. of Ophthalmol.*, August, 1941) it is necessary to employ the logarithmic expression of the units employed (log units) in plotting the adaptation curve if any accurate representation is to be obtained of the rapid changes in the early stages of adaptation.

The international candle is the recognised standard of the intensity of luminous emission from any source of light and is the basis of all other units employed. One candle power is the intensity of the light emitted by one standard international candle (1 Hefner is 0.9 of this and is the light emitted by the flame of a particular type of lamp). A foot candle is the intensity of the light at a distance of 1 foot and a metre candle at a distance of 1 metre.

A brief description (*see* Footnote) of the modern physical units used by some investigators of dark adaptation has been included partly to show, as mentioned above, that their primary basis is the light of one standard candle; and partly to assist those not acquainted with these units to convert them to the more familiar fractions of a candle power. The foot candle is a term which explains itself; it is a unit to which all clinicians would attach a definite meaning. It may safely be said that very few would understand the meaning of the lux or the lambert however valuable these terms may be to the pure physicist.

FOOTNOTE.—The lumen is the light unit of energy falling on (or emitted by) an area bounded by the sides of a pyramid with an angle of 57.3° (the solid radian) from a point of one standard candle power at the apex of the pyramid angle.

Thus the energy falling on any sectional area of the pyramid at whatever distance is the same.

Units based on the above are:—

The foot candle = 1 lumen per ft.² The lux = 1 lumen per m.²

Thus as 1 m.² = 10.75 ft.² to convert micro-lux into milli. ft. c., the figures for the former would have to be divided by 10760.

Therefore 1 m.f.c. = 10760 micro-lux; and 1 micro-lux = .0093 m.f.c.

The lambert is the unit of brightness. It is the brightness of a surface emitting 1 lumen per centimetre.

One sq. ft. = 930 cm.² (approx.). Therefore 1 lambert = 930 ft. c.

This being so, the micro-micro lambert = .00000093 m.f.c. The micro lambert = .93 m.f.c., and the milli. ft. c. = 1.075 micro lambert.