The mechanism of the accommodation could be, indeed, more easily explained if we might assume that the radial and circular fibres are supplied by branches from different nerves, and that they stand in a similar antagonistic relation to each other as the dilatator and sphincter pupillæ.

The chief argument against the theory that the eye accommodates itself actively for distant objects is in the action of a strong solution of atropine, which paralyses the power of accommodation, but does not interfere with the distant vision of the emmetropic eye, and does not change the position of the far point.

CHAPTER II.

RANGE OF ACCOMMODATION.

BEFORE we speak of the mode of examining the range of accommodation, it will be well to consider what test-types are the best for the purpose of determining the acuteness of vision, and the position of the near and far point. Formerly Jaeger's test-types were chiefly in use, but they did not afford us a perfect clue to the acuteness of vision; for a person might be able to read No. 1 of Jaeger, and yet not enjoy a normal acuteness of sight. Snellen has, however, devised a set of test-types which fulfil this desideratum. The letters are square, and their size increases at a definite ratio, so that each number is seen at an angle of 5 minutes. Thus, No. 1 is seen by a normal (emmetropic) eye up to a distance of 1 foot, at an angle of 5 minutes; No. 2 up to 2 feet, and so on. These numbers cannot, as a rule, be seen distinctly beyond these distances.*

* At Professor Longmore's suggestion, Dr. Snellen has given, in his later editions of the Test-types, some tables containing a series of figures and single numbers, for the examina-

Now, if the eye is suffering from any diminution of acuteness of vision, it will require to see the letters under a larger angle than that of 5 minutes, in order to gain larger retinal images. No. I cannot be read at a distance of 1′, but only, perhaps, No. IV. or V. We may easily calculate the degree of the acuteness of vision thus :

"The utmost distance at which the types are recognised (d) divided by the distance at which they appear at an angle of 5 minutes (D), gives the formula for the acuteness of vision (V).

$$V = \frac{d}{D}$$

"If d and D be found equal, and No. XX be thus visible at a distance of 20 feet, then $V = \frac{20}{20} = 1$; in other words, there is normal acuteness of vision. If, on the contrary, d be less than D, and if No. XX is only visible within 10 feet, No. X only within 2 feet, No. VI only

tion of such recruits for the British army as are unable to read. For further information as to the examination of the sight of recruits, I must refer the reader to Professor Longmore's excellent "Ophthalmic Manual," which I would also recommend to the special notice of the surgeons of the Militia and of Volunteer corps. These test-types may be obtained from Messrs. Williams and Norgate, Henrietta Street, Covent Garden.

within 1 foot, these three cases are thus respectively expressed :—

$$V = \frac{10}{20} = \frac{1}{2}$$
$$V = \frac{2}{10} = \frac{1}{5}$$
$$V = \frac{1}{6}$$

d may sometimes be greater than D, and No. XX be visible at a greater distance than 20 feet. In such cases the acuteness of vision is greater than the normal average." (Snellen.)

It must, however, be confessed that some patients (more especially amongst the lower classes) often experience a difficulty in fluently reading type composed of these square letters. They have always been accustomed to ordinary type, the letters of which are of unequal thickness, and differ both in dimension and definition. I, therefore, generally employ Jaeger's test-types for ascertaining the fluency with which small print can be read, and those of Snellen, for testing with accuracy the acuteness of vision.

When the eye has assumed its highest state of refraction, it is accommodated for its nearest point of distinct vision; when its state of refraction is, on the other hand, relaxed to the utmost, it is adjusted for its furthest point.

The power of the ciliary muscle is, however, limited; and consequently the lens is only capable of a certain increase in its convexity, and the accommodation for near objects has, therefore, also its limit, and the near point cannot be brought nearer than a certain distance from the eye. In normal eyes the nearest point of distinct vision lies at about $3\frac{1}{2}$ or 4 inches from the eye; this varies, however, according to the age of the patient, for, as we shall afterwards show, the near point recedes further and further from the eye with advancing years. For continued work at near objects—engraving, &c.—the near point lies at about 5 inches. Few eyes, indeed, can bear to work for any length of time with the object nearer than this. The furthest point of distinct vision in the normal eye is at an infinite distance (parallel rays).

The distance between the furthest point (r), *and the nearest point* (p) *of distinct vision is called the territory or range of accommodation.* The extent of this range must vary, of course, according to the strength and efficiency of the ciliary muscle, the elasticity of the lens, and the age of the patient.

The distance of p from the eye (measured from the nodal point) is expressed by P, the distance of

r from the eye by R; and we may easily find the range of accommodation $(\frac{1}{A})$ by the following formula:—

$$\frac{1}{A} = \frac{1}{P} - \frac{1}{R}$$

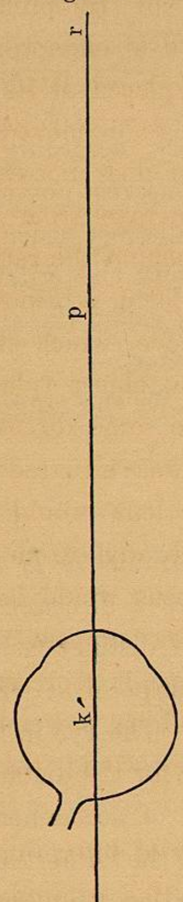
The distances P and R may, according to Donders, be calculated from the nearest point, p, and from the furthest point, r, of distinct vision, to a point situated about 3‴ behind the anterior surface of the cornea in the eye, called the anterior nodal point, k'. He says, further:—

"The meaning of the formula for the range of accommodation—

$$\frac{1}{A} = \frac{1}{P} - \frac{1}{R}$$

is easily understood. In this formula A is the focal length of a lens, which gives a direction to the rays from the nearest point of distinct vision, p, as if they come from the farthest point, r. The subjoined Fig. (15) illustrates this. The eye in the condition of rest, is accommodated for the distance $r\,k' = R$; in the strongest tension of accommodation for the distance $p\,k' = P$. In the former case, the rays diverging from r are united on the retina; in the latter those diverging from p. In accommodation, therefore, the eye must be so altered, that the rays proceeding from p, in the vitreous humour, acquire a direction equal to that of the rays proceeding from r in the non-accommodated eye. This can be effected by placing an auxiliary lens in k', and we may thus imagine the eye away, and suppose that the auxiliary lens in k' is in the air. The lens now represents the accommodation of the eye, and its power the range of accommodation. The focal distance, A, is found by the formula mentioned:—

Fig. 15.



$$\frac{1}{P} - \frac{1}{R} = \frac{1}{A}$$

Consequently, A is the focal distance of the auxiliary lens, of which the eye avails itself in accommodation, and as the power of a lens is inversely proportional to its focal distance, $\frac{1}{A}$ or $1 : A$, expresses the range of accommodation. It is convenient to represent the value of A in Parisian inches, especially as the focal distance of lenses is usually stated in the same, and

this applies also more particularly to spectacles."* (Donders, p. 30).

To render this still easier of comprehension, let us suppose that the eye is emmetropic and accommodated for an object placed at its far point (parallel rays), if the object is now moved up to 5″ from the eye, and the latter does not exert its power of accommodation, the rays from the object will be brought to a focus behind the retina. In order to unite them upon the latter a biconvex lens must be placed before the eye, which shall render the rays coming from the object (placed at 5″) parallel, *i.e.*, give them the same direction as they had when the object was situated at an infinite distance. A 5-inch lens would be required for this purpose, for the rays from an object situated at its anterior focus would issue parallel from the lens. If we now suppose this auxiliary lens placed within the eye, it represents the accommodation of the eye, and its power the range of accommodation, the latter would, therefore, in this case = $\frac{1}{5}$.

Let us illustrate Donders' way of determining the range of accommodation by a few examples;

* The lenses in the boxes of Paetz and Flohr of Berlin are defined in Prussian inches, which are very nearly the same as the English inches, and less than the Parisian.

first again, however, explaining the meaning of the following expressions :—*A* signifies range of accommodation; *r*, far point; *p*, near point; ∞ (= 0), infinite distance; ′, foot; ″, inch; ‴, line.

1. Normal eyes, which can see from an infinite distance up to 5″ from the anterior surface of the crystalline lens, have their far point (*r*) at an infinite distance (∞), their near point (*p*) at 5″. In order to find the range of accommodation of such an eye, we apply the above formula, $\frac{1}{A} = \frac{1}{P} - \frac{1}{R}$. In our case r = ∞, p. = 5″ therefore $\frac{1}{A} = \frac{1}{5} - \frac{1}{\infty} = \frac{1}{5}$.

The range of accommodation is here represented by an auxiliary lens of 5 inches.

2. Let us test the range of accommodation of a short-sighted, or myopic eye. Let us suppose that its far point (*r*) lies at 8″ from the eye, its near point (*p*) at 4″, $\frac{1}{A}$ therefore $= \frac{1}{4} - \frac{1}{8} = \frac{1}{8}$.

3. If a presbyopic, or far-sighted eye, has its far point (*r*) at an infinite distance, and its near point at 10″, $\frac{1}{A}$ will be $\frac{1}{10}$, for $\frac{1}{10} - \frac{1}{\infty} = \frac{1}{10}$.

I shall afterwards, when speaking of hypermetropia, mention the best plan of examining the range of accommodation of a hypermetropic eye.

The following is also a very good method for testing the range of accommodation, and for

quickly discovering whether the eye is myopic, hypermetropic, or presbyopic :—

A convex lens of 6″ or 10″ focus is placed before the eye.* With this lens the patient then reads No. 1 of Snellen, and his far and near point are noted. The far (*r′*) and near point (*p′*) thus found, stand in such a relation to his real far (*r*) and near point (*p*), that the rays coming from *r′* are refracted by the lens as if they came from *r*, those from *p′* being also refracted as if they emanated from *p*. With convex 6, *r′* (in the normal eye) lies at 6″ from the eye, for rays from an object at 6″ distance falling on this lens would be rendered parallel by it, and would, consequently, impinge upon the eye as if they came from an infinite distance (the normal far point). The near point (*p′*) would lie at about $2\frac{2}{3}$″. This varies, however, with the age of the patient.

The range of accommodation is, therefore, easily found by the formula $\frac{1}{A} = \frac{1}{P} - \frac{1}{R}$. The lens and its distance from the eye (about $\frac{1}{2}$″) are omitted in the calculation.

* The lens must be strong in order that the patient may really command his far point, and that the latter may be approximated so much that the minimum of the angle of distinction no longer exerts any influence, and amblyopia is therefore excluded.

If (with convex 6) the far point (r') lies at 6″, the near point (p') at 3″, $\frac{1}{A} = \frac{1}{3} - \frac{1}{6} = \frac{1}{6}$.

Let us illustrate this proceeding by the following examples :—

I. *Myopic eye.* We find that with convex 6 $r' = 5''$, $p' = 3''$. The eye is consequently myopic, for it is not adjusted for the normal far point (6″), but for a nearer one, the rays from which impinge in a divergent direction upon the eye :—

$$\frac{1}{A} = \frac{1}{3} - \frac{1}{5} = \frac{1}{7\frac{1}{2}}.$$

Now, what glasses will this patient require for infinite distance ? By means of our strong convex lens we have changed this eye into a very myopic one, in fact, into a myopia of $\frac{1}{5}$, for we should have to place a concave glass of 5″ focus before convex 6 in order to enable it to see at a distance ; for this concave glass would render parallel rays so divergent as if they came from 5″ distance. In order to find the proper concave glass for distance, we deduct concave 5 from convex 6. Hence the proper concave glass will be No. 30 for

$$\frac{1}{6} - \frac{1}{5} = - \frac{1}{30}$$

II. *Hypermetropic eye.* With convex 6, $r' = 8$,

$p' = 3''$. The eye is, therefore, hypermetropic, for its far point lies beyond the normal far point (6″).

Its range of accommodation $= \frac{1}{4\frac{4}{5}}$ for

$$\frac{1}{A} = \frac{1}{3} - \frac{1}{8} = \frac{1}{4\frac{4}{5}}$$

Although we can thus very quickly determine the fact that the eye is hypermetropic, and also its range of accommodation, we cannot find with exactitude the requisite convex glass for distance by the same calculation as in the myopic eye ; for, as we shall, hereafter, show, the amount of hypermetropia before and after the paralysis of the ciliary muscle by atropine sometimes varies greatly.

Above, we have only spoken of the *absolute* range of accommodation which exists when each eye is tried separately. Donders* has, however, pointed out that we must distinguish two other kinds of ranges, viz., the *binocular* and the *relative.* The *binocular* comprises the accommodation from the furthest point r_2 to the nearest point p_2, when both eyes are tried together. The formula is $\frac{1}{A_2} = \frac{1}{P_2} - \frac{1}{R_2}$.

Although a certain connection exists between

* Op. cit., 110. Full explanations, with explanatory diagrams of this subject, will be found in Donders' work.

the accommodation and the convergence of the visual lines, yet this connection is not absolute and definite, for we find that the position of the visual lines may be changed, yet the accommodation remain the same; for if a prism of moderate strength be placed with its base outwards before one eye, the convergence of the visual lines will be greatly increased to overcome the diplopia, and yet the object can be distinctly seen at the same distance with both eyes. Again, the accommodation may be altered, and yet the state of convergence remain the same, for if we place weak concave or convex lenses before the eyes, an object can still be distinctly seen at a definite distance. This proves that the accommodation may be modified without any change of the convergence of the visual lines. These experiments show that there exists a certain independence between the convergence and the accommodation, and the range of accommodation over which we have control at a given convergence of the visual lines is termed the *relative* range, and is found by the formula $\frac{1}{A_1} = \frac{1}{P_1} - \frac{1}{R_1}$. It consists, moreover, of two parts, the *positive* and the *negative*. The positive being the part which is disposable for a distance closer than the point of convergence, whereas the negative is the portion

which is required to see an object lying beyond the point of convergence of the visual lines. Now the relation between these two parts of the relative range of accommodation is of much practical importance, for it is found that, in order that the eyes may be employed comfortably for some length of time at near objects (reading, etc.), it is absolutely necessary that the positive part of the accommodation should bear a certain proportion to the negative (it should at the very least be equal to $\frac{1}{2}$).

The best objects for testing the range of accommodation are Snellen's test types or Von Graefe's wire optometer. But as the latter requires some exactitude and intelligence on the part of the patient, I find it more practical, especially with hospital patients, to use the test types. If, whilst they are reading No. 1, we move the type a few times alternately nearer to and further from the eye, the nearest and furthest point of distinct vision can be readily ascertained. Von Graefe's optometer consists of a small square steel frame, across which a number of delicate, parallel, vertical wires are stretched. This frame may be attached to a brass rod (graduated in inches and feet) upon which it is moveable; or it may be fastened to a graduated tape. One end of the rod or the bobbin of the tape is placed against the forehead of the patient, and the frame moved to the nearest point at which the individual wires still look clearly and sharply defined; the distance of this point from the eye is read off from the graduated scale, and put down as the near point (p). The frame is then removed to the greatest distance at which the individual wires still appear sharply defined, and this is noted as the far point (r). The distance between p and r gives the range of accommodation. The wires only appear sharply defined when the eye accommodates itself perfectly for them, directly there is the slightest deviation from this perfect accommodation (the frame being too far from or too near to the eye), the wires seem indistinct, thickened, or as if surrounded by a halo; or coloured double images of them may even appear in the transparent intervals. With the test types, the examination is still easier, the nearest point at which No. 1 (Snellen) can be distinctly and comfortably read is ascertained, and noted as the near point, and then the furthest point (in an emmetropic eye No. 1 of Snellen should be read up to 1′, No. xx up to 20′), is measured and noted.

CHAPTER III.

MYOPIA.

SHORT-SIGHTED persons generally apply to us with the complaint that, although they are able to distinguish the very finest objects near at hand, they cannot see well at a distance. This depends upon the fact, that the refracting power of the eye is increased in myopia, or that the antero-posterior axis of the eyeball is too long, so that parallel rays (emanating from objects at an infinite distance), or even not sufficiently divergent rays, are brought to a focus before the retina; circles of diffusion are formed upon the latter, and in consequence of this, the distant object does not appear clear and sharply defined, but indistinct and blurred. Such patients notice, for instance, that the stars, the moon, or a gas-lamp in the streets, do not present a clear and well defined outline, but appear irregular, enlarged, and as if surrounded by a halo. In order, therefore, to improve their vision for distant objects, they often acquire the habit of nipping their eyelids together. The reason for