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ON

THE PATHOGENY OF SQUINT.

BY

PROFESSOR DONDERS, OF UTRECHT;

TRANSLATED FROM THE GERMAN,

WITH A PREFACE.

BY

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TO

SIR WILLIAM R. WILDE,

SURGEON OCULIST IN ORDINARY, IN IRELAND, TO THE QUEEN,
SURGEON TO ST. MARK'S OPHTHALMIC HOSPITAL,
ETC., ETC., ETC.,

THIS TRANSLATION OF PROFESSOR DONDERS'S MEMOIR
ON THE PATHOGENY OF SQUINT,

IS

Dedicated,

AS A SLIGHT TOKEN OF ESTEEM FOR ONE WHO HAS DONE VERY MUCH FOR
OPHTHALMIC SURGERY IN IRELAND,
AND OF GRATITUDE FOR MANY KINDNESSES,
BY HIS FRIEND AND FORMER PUPIL,

The Translator.

PREFACE.

PERHAPS no affection of the eyes has attracted more notice than that of squint, and yet it is only within the last few years that attempts have been made to remedy it by means of an operation. It is scarcely a quarter of a century since Cunier and Dieffenbach operated for the cure of squint, by cutting the recti muscles—an operation which became, at once, popular. Thousands of cases were thus treated, and many of them very successfully; but in a comparatively short time this operation fell, more or less, into disrepute, and for years has, in these countries, been but little heard of.

Giraud Teulon, in his *Leçons sur le Strabismé*,[a] says, in speaking of France, "The study of strabismus may, in effect, be considered among us as not only in a state of sleep, but as absolutely dead." This arose, in some measure, from the fact that so little was really known as to the etiology of this affection; for we find that on this subject the most diverse opinions were held, and the literature of this portion of ophthalmic surgery is as excursive as it is large. Among the causes most commonly assigned for the origin of squint, in the numerous manuals and text books of the present day, are—convulsions, difficult dentition, worms, blows on the eye, irritation, and many other such like; thus, Dr. Mackenzie,[b] in his classical treatise *On the Diseases of the Eye*, enumerates, among other causes of squint, fits of passion, fright, children looking at the point of their noses, &c.; and Dr. Haynes Walton,[c] while he ventures a guess as to "the balance of antagonistic power in the orbital muscles being very nice, and having something to say to squint," yet candidly

[a] Leçons sur le Strabismé, et la Diplopie Pathogénie, et Thérapeutique, par F. Giraud Teulon. Paris, 1863.

[b] Practical Treatise of Diseases of the Eye. 4th edition, 1854, p. 348.

[c] Surgical Diseases of the Eye. 2nd edition, 1861, p. 375.

acknowledges that "while derangement in the visual apparatus, opacity of the cornea and of the lens, comprise the circumstances that may induce it, yet, in the *majority of cases*, it really cannot be accounted for, as it frequently occurs in the healthiest of children." And so it happened that the profession not only began to talk of the operation for squint in very disparaging terms, but they generally discouraged patients or their friends from allowing the operation to be performed.

The first important modern contribution to our knowledge of squint was by von Graefe. His memoir on strabismus, in the third volume of the *Archiv für Ophthalmologie*, marked quite a new era in this department of surgery. The enormous opportunities enjoyed by von Graefe, coupled with a power of observation peculiarly his own, have enabled him to lay down certain laws for our guidance in operating, the want of which has been too often felt by the surgeon. Having, first of all, determined which eye is affected; the amount of deviation; the quantity and quality of sight possessed by the eye, &c.; then comes the very important question—if the deviation be two lines or two lines and a-half, what amount of operation is necessary to remove this deviation? Detailed answers to all such questions were now, for the first time, given by Graefe, and given as the result of his long experience. The importance of this very practical paper of the great Berlin oculist cannot well be overrated; and, if I refrain from giving extracts from it here, it is only because I know that a translation is expected from the pen of one of his most distinguished English pupils, and because Giraud Teulon's work is, to a certain extent, but an amplification of von Graefe's memoirs. But, even after its publication, the pathogeny of squint was almost as little known as before; and the great value of Professor Donders's paper appears to me to be, that it clears up just the very portion of this subject on which we most of all wanted enlightenment. This paper—an almost literal translation of which I herewith present for the perusal of my professional brethren—will, perhaps, be better understood if I very briefly allude to the classification of eyes that Professor Donders adopts:—

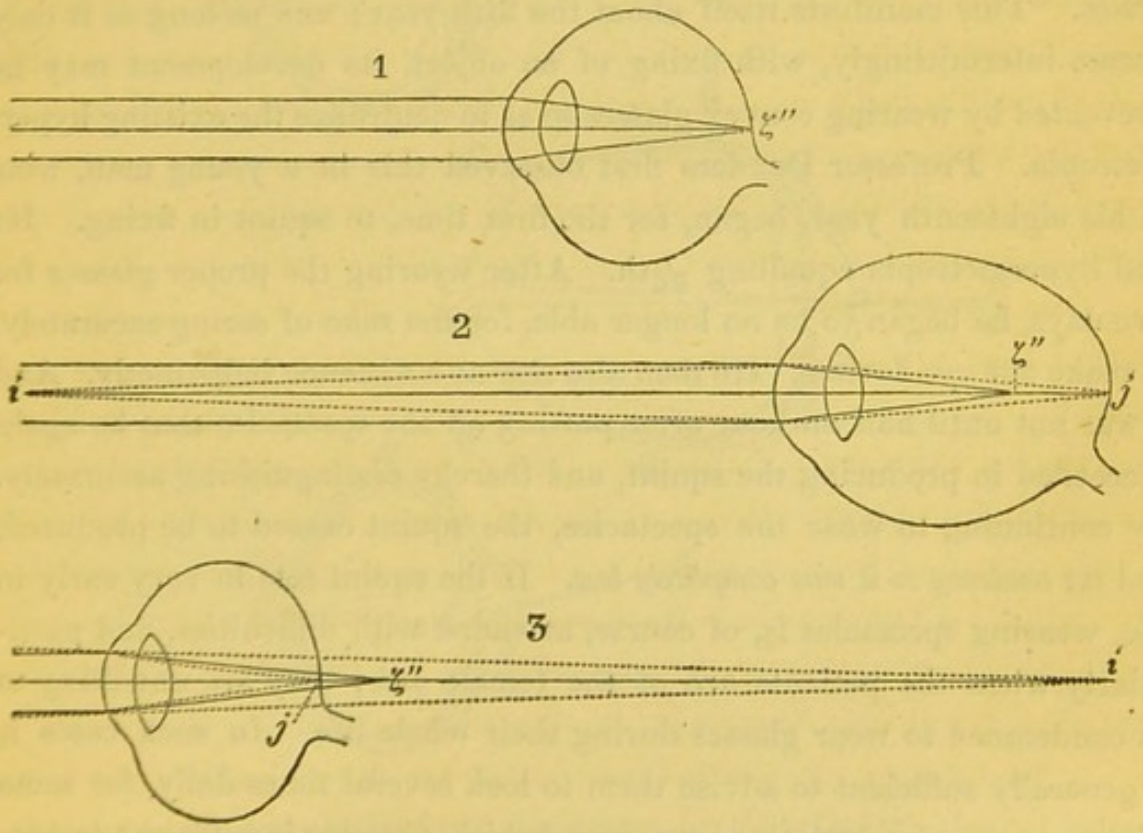
1st. *Normal*, or *emmetropic eyes*, in which, when the eye is at rest, parallel rays are brought to a focus on the retina. When the normal eye is in a state of rest the focal point of its dioptric system is situated on the pacillar layer of the retina.

2nd. *Myopic*, or *brachymetropic eyes*, which are adjusted when in a state of rest, for divergent rays. In this case parallel rays are, even when the

eye accommodates itself for its farthest point, brought to a focus before the retina, so that distinct images are formed on the retina only of those objects the rays of which impinge divergently upon the eye. In the myopic eye, when in a state of rest, the focal point of the dioptric system lies before the retina.

3rd. *Hypermetropic eyes* are adjusted for convergent rays. In this case parallel rays are brought to a focus behind the retina when the eye is at rest; for in hypermetropic eyes the focal point of the dioptric system lies, when the eye is in a state of rest, behind the ciliar layer of the retina.

The accompanying illustrations, taken from Professor Donders's work *On the Anomalies of Accommodation and Refraction of the Eye*,[a] will make this classification more easily understood. Figure 1 represents the emme-



tropic eye, where the principal focus of the media of the eye at rest falls on the anterior surface of the most external layer of the retina, as at ζ''. In Fig. 2 the principal focus, ζ'', of the eye at rest falls in front of, and in Fig. 3 behind, the retina. In the former case divergent (dotted in the figure), in the latter convergent rays come to a focus on the retina. In the first case, therefore, in the condition of rest, objects are accurately

[a] Translated by W. D. Moore, M.D. New Sydenham Society for 1864. From this excellent translation of a most valuable work I have borrowed freely in writing these pages.

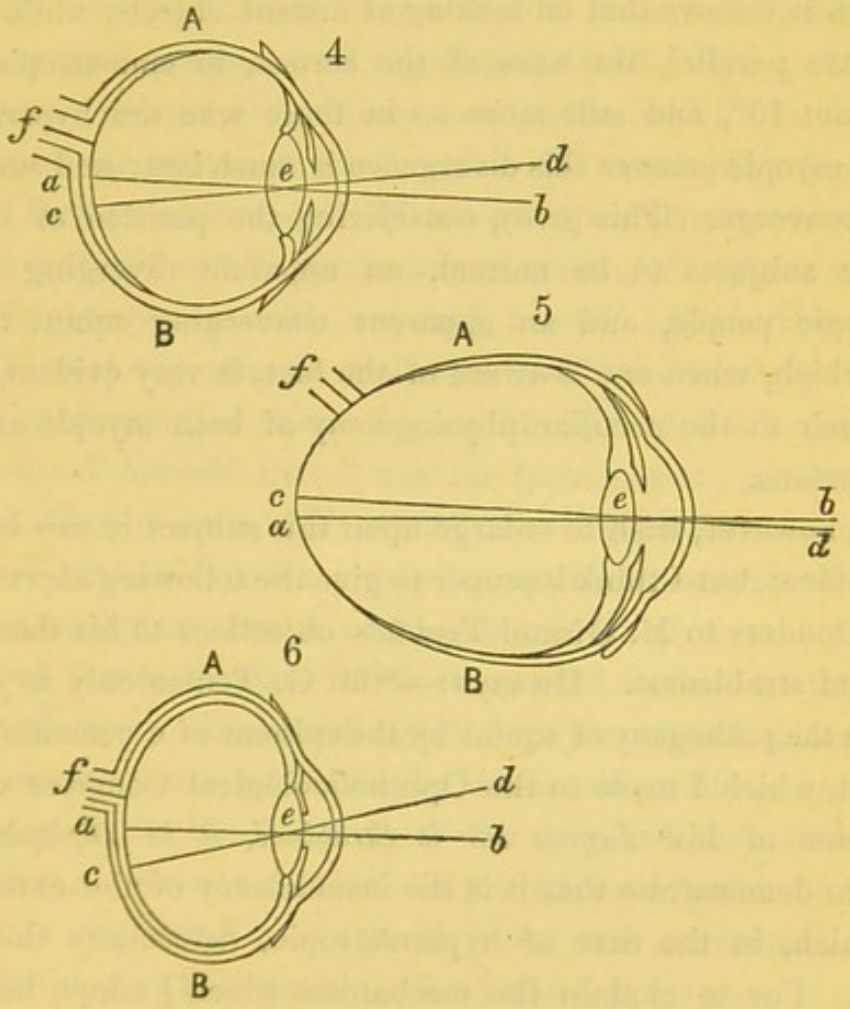
seen which are situated at a definite finite distance (Fig. 2, *i.*); in the second case they are, at no distance, accurately seen—for the rays, in falling upon the cornea, must, in order to unite in the retina, already converge towards a point situated behind the eye (Fig. 3, *i.*).

Professor Donders's paper proves that in this last class of eye converging squint is very often found, whereas in the second we very frequently find diverging squint. For example, a person with one eye hypermetropic, in order to try and obtain more distinct vision, at first slightly converges this eye; by this, however, double vision occurs, which is more distressing than even the previous indistinct vision; and, to avoid this, the eye either converges a little more or the image of the eye is suppressed. In the latter case, the sight of this eye becomes impaired, and in process of time is completely lost; in the former, a well-marked converging squint arises. This manifests itself about the fifth year; and as long as it only occurs intermittingly, with fixing of an object, its development may be prevented by wearing convex glasses so as to neutralize the existing hypermetropia. Professor Donders first observed this in a young man, who, in his eighteenth year, began, for the first time, to squint in fixing. He had hypermetropia equalling $\frac{1}{20}$th. After wearing the proper glasses for two days, he began to be no longer able, for the sake of seeing accurately, to make one eye deviate. He then also saw at a distance indistinctly. And it was not until half an hour after putting off the spectacles that he again succeeded in producing the squint, and thereby distinguishing accurately. By continuing to wear the spectacles, the squint ceased to be produced, and *the tendency to it was completely lost.* If the squint sets in very early in life, wearing spectacles is, of course, attended with difficulties, and particularly when the patients are of the female sex; they are unwilling to be condemned to wear glasses during their whole life. In such cases it is generally sufficient to advise them to look several times daily, for some minutes, with the deviating eye alone, which practice is sufficient to prevent the diminution of the acuteness, and the limitation of the field of vision; at a later period—when the squint is confirmed—the operation of tenotomy is performed. Where the patient prefers obviating the squint by wearing proper glasses, Professor Donders willingly consents, and has found the object almost invariably obtained. Dr. Mooren,[a] too, has recently stated that where a tolerably high degree of hypermetropia existed, he has, in the first stage of strabismus, prescribed with good

[a] Klinische Monatsblätter für Augenheilkunde. B 1, H 1, 1863.

results the use of convex glasses.[a] In comparatively high degrees of hypermetropia, the prevention of squint is in fact more particularly desirable, because subsequently, even after complete tenotomy, the tendency to squint continues; and in order to prevent a relapse, the use of convex glasses, at least for close work, is still most necessary.

Here, perhaps, it is advisable to show, by means of a diagrammatic sketch, the difference in the angle α, so often referred to in this translation, of the emmetropic, myopic, and hypermetropic eye—referring, for more minute details, to page 4 of the Translation. In Figs. 4, 5, and 6,



these eyes are seen in horizontal sections, carried through the optic nerve; A is, therefore, the innermost, and B the outermost part of the eye. The axis of the cornea, *a*, *b*, cuts the cornea in the middle; to this, in fact, the apex of the ellipsoid of the cornea corresponds. But this axis is by no means directed to the object fixed, which, as such, has its image in the yellow spot *c*. A line drawn from the retinal image of this spot towards its object is the line of vision *c*, *d*, and this may be considered

[a] I am aware of Dr. A. Gräfe's paper in answer to these statements of Dr. Mooren, which appears in the same journal.

to cut the axis of the cornea in the united nodal point *e*. The angle *d*, *e*, *b* (angle *a*), is, therefore, the angle between the axis of the cornea and the line of vision in the horizontal plane. In the vertical plane this angle is usually much less, and has no special bearing on the present subject. Now it appears that in the emmetropic eye the line of vision cuts the cornea to the inside of its axis. In myopic individuals the angle *d*, *e*, *b*, is less than in emmetropic persons; and in the highest degree of myopia the cornea may be cut by the line of vision even on the outside of its axis; on the contrary, this angle is, in hypermetropia, particularly large. From which it follows that on looking at distant objects, while the lines of vision are parallel, the axes of the cornea, in emmetropic persons, diverge about 10°, and still more so in those who are hypermetropic; but that in myopic persons this divergence is much less; and such persons may even converge. This gives, considering the position of the eye in emmetropic subjects to be normal, an apparent diverging squint to hypermetropic people, and an apparent converging squint to myopic persons—which, when one is aware of the fact, is very evident, and contributes much to the peculiar physiognomy of both myopic and hypermetropic persons.

I do not, however, wish to enlarge upon this subject in this brief introductory preface; but I think it proper to give the following short answer of Professor Donders to M. Giraud Teulon's objections to his theory of the pathogeny of strabismus. He says:—"M. G. Teulon only as yet knows my ideas on the pathogeny of squint by the epitome of a communication on this subject which I made to the Ophthalmological Congress of Paris.[a] In a chapter of his[b] *Leçons sur le Strabismé, et la Diplopie*, he has attempted to demonstrate that it is the insufficiency of the external recti muscles which, in the case of hypermetropia, determines this kind of strabismus. For to explain the mechanism which I adopt, he cites the following words:—'While casually looking towards distant objects, without making any effort, the hypermetropic person will present, to an attentive observer, a state of apparent diverging squint; but when he wishes to accommodate, in order to see more distinctly—as the accommodation receives a powerful assistance by the synergique act of convergence, the hypermetropic person, in whom the accommodative power is

[a] *Vide* Congres Periodique International d'Ophthalmologie. Compte-rendu. 2e Session. Paris, 1862. Article xx., pp. 148-153. Meeting of the 3rd October.

[b] L. c., page 78.

more or less deficient, can, by convergence, assist this defective action. But the convergence, in changing the line of vision, brings on, as its consequence, diplopia. And we have a dislike to double images; there is, therefore, a combat between the desire to see objects sharply, and the necessity—not less imperious—to see single. More often the accommodation is sacrificed—sometimes, however, it is the simple binocular vision. This is what happens, for example, when the eyes are very unequal in quality. In the other case one sacrifices, without hesitation, the less distinct image. When the convergence is fearlessly called to the aid of the defective accommodation, it produces a *convergent squint*.' It has, unhappily, escaped the notice of my distinguished *confrère*, that I admit, however, 'two orders of auxiliary conditions, which, in the case of hypermetropia, contribute to produce this affection. The first, I state, is a certain facility—a congenitally too great convergence—*a disposition which can be connected with the insufficiency of action of the external rectus.* The second is in connexion with external causes.' (*Vide* Compte-rendu, p. 151.) Now if my memoir had been published in full, in French, before the publication of these *Leçons*, M. Giraud Teulon could have better convinced himself that I was far from neglecting the primitive tendency of these muscles. He would have found, demonstrated in an exact manner, that this tendency may favour, in general, the development of squint among hypermetropic people, on account of the relatively large divergence of the optic axes, which correspond to the direction parallel to the lines of vision. He would, again, have seen that I collect into two classes the circumstances which favour the development of squint among hypermetropic people, the difference of the eyes, and the tendency of the muscles, either absolute or relative. My excellent friend is, it appears to me, wrong in neglecting the first of these, and attributing all to the second. But he goes still further. That which is for me a circumstance which favours squint, is for him the true cause, principal, or unique. This cause is not, according to his view, hypermetropia itself, and the difficulty of accommodation proportionate to the convergence, but it is the insufficiency of the external recti which so often accompanies hypermetropia. M. Giraud Teulon cites the following experiment, which, he says, he has often tried:—'Let us place before one of our eyes a concave glass proportionably strong ($\frac{1}{13}$); the other eye having a convex glass of the same number, we thereby render ourselves hypermetropic on the one side, and not less myopic on the other; now, fixing our looks on

some distant object, no effort will ever allow the two images to be dissociated, however obscure and unequal they may be. The necessity of a single sensation at least of the two images is much too imperious to admit of a dissociation of images once fused.' If, instead of placing the concave glasses before but one eye, the experimenter had placed them before both—and if, instead of trying the experiment on himself, he had tried it on very young people, with a great latitude of accommodation, and having also that flexibility of organization peculiar to youth—he would have found that they had *a great tendency* to see double; and some of them would have told him that they felt inclined to sacrifice double vision in order that they might see those objects better which they wished to examine. For the rest—the mode of development of converging strabismus, which for the most part is only shown at the momont of fixing for near objects, and especially that which follows after tenotomy—viz., a voluntary strabismus, tending to overcome the hypermetropia (Compte-rendu, p. 152)—leaves no doubt on my mind of the direct part that hypermetropia plays on the production of converging strabismus. As to the other experiment of M. Giraud Teulon, which consists in placing before one of the eyes a prism with its base to the nose, it only proves what I assigned to it in my first work on prismatic glasses—that is to say, that we are unable to make the lines of vision diverge to any great degree.

"The observations of the learned ophthalmologist of Paris are not, then, of a nature to modify the ideas which I have brought forward on the production of converging strabismus. I wish, nevertheless, to take this opportunity of thanking him for the gracious manner in which he has spoken, and for the clear way that he has presented these very essential views of the pathogeny of squint."

In conclusion, I have only to state my conviction, that many eyes are irrecoverably lost, owing to the strange prejudice that exists against operating for squint in early life, the very time, of all others, when the sight is most susceptible of improvement.

My best thanks are due to Professor Donders for his kindness in revising this translation, and for suggesting improvements in many parts.

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ON THE

PATHOGENY OF STRABISMUS.

STRABISMUS may be defined as a deviation of the eyes, in consequence of which the two yellow spots receive, simultaneously, the impression of different objects. The lines of vision do not intersect at the point which one wishes to see—one of the two only, that of the unaffected eye, being directed towards this point. This deviation not only alters the physiognomy, by the want of symmetry of the parts of the face which contribute the most to its expression, but it troubles the vision at least of one of the eyes, and there is, in every instance, a loss of the advantages of binocular vision.

Strabismus, however, does not, by itself, constitute a definite pathological condition; it is only a symptom which depends upon affections of a very varied nature, and which may accompany other very different pathological signs. Those who would undertake to write a manual of ophthalmology, and to treat, systematically, of all eye affections, would, in many places, have to treat of strabismus as more or less belonging to very different diseases. Strabismus will frequently present itself as a constituent of a composite anomaly, in which it is connected with the originating cause, and with all the functional disturbances which result therefrom; but it cannot be treated of as a special malady—it is only the semeiologist who could treat of strabismus in general. Although this proposition has been admitted for a long time as true, yet it has by no means been acted upon. Open a manual of ophthalmology. A chapter is devoted to the subject, and in it all that relates to the deviations of the eyes is alluded to; elsewhere it is but referred to in passing. Even when it treats of its etiology, we find the different forms of strabismus brought together, although in their origin they do not resemble each other

in the least. In the monographs it is not much better. Is it then strange that the pathogeny of strabismus is still so obscure? It appears to be part of man's nature to attribute to each phenomenon an external cause, and to admit as such the first that presents itself. Even pathology has not yet entirely liberated itself from this levity and credulity. As far at least as strabismus is concerned, its causation has often been searched for in the most fortuitous circumstances—looking for information to nurses and mothers—while the veritable origin of the disease, which resides in the form of the eye, has been overlooked.

A few years ago we became acquainted with one of the anomalies of refraction—hypermetropia—in which the focal point of the dioptric system, in a state of rest, lies behind the retina. After having discovered the slighter degrees of this anomaly, which may exist in a latent condition, I quickly came to the conviction that it is on it that asthenopia and convergent strabismus depend—whose origin until then had remained problematical.

Elsewhere[1] I have treated, in detail, on hypermetropia as a cause of asthenopia; I have admitted that the insufficiency of the recti interni muscles, as pointed out by von Graefe,[2] may produce pathological phenomena having a great affinity with those of asthenopia, following hypermetropia; but I have added that cases of this kind are relatively very rare; we find, in studying the causes of diverging strabismus, that they occur very frequently with a certain degree of myopia. Further, I have mentioned that the greater the degree of the accommodation $\frac{1}{A}$ is, so much the greater can the hypermetropia be without causing asthenopia; and, therefore, the later the asthenopia is in developing itself the less is the hypermetropia; I may add that the age at which asthenopia commences, corresponds very nearly to the denominator of the fraction which expresses the degree of hypermetropia. Lastly, I have remarked, that the feebleness of the accommodation, whether owing to general or local causes, favours the development of asthenopia. I have since published some observations[3] on diminution of accommodation, of a diphtheritic origin, which had produced symptoms, which one could never determine, at first sight, from those of asthenopia from hypermetropia.

[1] Ametropie en hare gevolgen. Utrecht, 1860, bl. 30. Archiv für Ophthalmologie. Bd. vi. 1, S. 78 u. f.

[2] Archiv für Ophthalmologie. Bd. iii., Abth. 1, S. 308.

[3] Tijdschrift voor Geneeskunde, 1860. D. vi., bl. 657. Archiv für die Holländ. Beiträge zur Natur—und Heilkunde von Donders und Berlin. Bd. ii., S. 453.

I have treated only[4] incidentally of hypermetropia, as a cause of convergent strabismus; nevertheless, it is now some time since I published the results of my observations relative to this subject. Indeed, I never lost sight of the subject; but I desired to examine, thoroughly, and investigate, for every class of cases, what those anomalies of vision are with which the different forms of strabismus may be connected: it appeared to me that researches of this nature would tend, most surely, to elucidate the pathogeny of strabismus. These anomalies are treated of, from a general point of view, in the following pages, wherein I give the result of particular cases.

The inquiry is one best determined by statistics, and I have already investigated in a very great number of cases affected with strabismus—and for both eyes—all that appeared to me to be either a cause, or a consequence of the deviation of the visual line, or to be of a nature to throw light, some day, on the development of these affections. I have taken notes of the sex, age, and habitual occupations in all these cases. The state of refraction has been accurately ascertained for each individual eye—the extent of accommodation, the degree of acuteness of vision, the extent of movements, these latter in connexion with the variable, or not variable, angle of deviation; and to these I have added others concerning the time and manner of the origin of the deviations; heriditary influence, and the different complications and functional disturbances (diminution of the extent of the field, of vision, diplopia, &c.) which accompany it. I have been very warmly assisted in these researches by many of my pupils, among others by Dr. Haffmans; I have thus been able to register over 280 cases. It is true that in many of these it was not possible to determine all the points above alluded to, and that in others all the precision desirable was not to be obtained. This will not surprise those who know, by experience, how arduous and difficult a thing it is to examine the eyes, with respect to their functions, in children or in adults, with but little mental cultivation. Nevertheless, this need not hinder us from determining, in a very satisfactory manner, from the collected data, a large number of questions of the greatest importance in the treatment of strabismus. At present I intend to occupy myself more especially with the pathogeny of this affection, and to examine, in particular, the influence which the various states of refraction of the eyes have upon it.

[4] Archiv für Ophthalmologie. Bd. vi., 1, S. 92.

According to the direction of the deviation we may distinguish two principal forms of strabismus—converging strabismus, and diverging strabismus. The conclusions to which our researches have conducted us may be summed up in the two following propositions:—

1. CONVERGING STRABISMUS IS MOST FREQUENTLY A RESULT OF HYPERMETROPIA.

2. DIVERGING STRABISMUS IS MOST FREQUENTLY A CONSEQUENCE OF MYOPIA.

We shall now proceed to examine, in detail, these two species of strabismus; saying a few words, in the first place, about apparent strabismus.

I. ON APPARENT STRABISMUS.

When two eyes, which are free from strabismus, steadily regard an object placed at an infinite distance, the lines of vision—those which go from the yellow spot through the optic centre—are parallel. If they are *not* so, there must exist a true strabismus. When they are so, there may, nevertheless, exist an apparent strabismus.

In effect, we judge of the existence of strabismus by the direction of the axes of the cornea, in viewing objects at different distances: for, if the axis of the cornea is not in its normal relation with the line of vision, there appears to be a strabismus, although the lines of vision may not have deviated in the slightest. This apparent strabismus plays an important part in the development of true strabismus; hence we proceed to say a few words in reference to it:—

In normal (emmetropic) eyes, while looking at distant objects, the visual lines are parallel—the axes of the cornea appear to have an identical direction, that is to say, they appear to be parallel. This is, however, a mistake; the lines of vision cut the cornea on the inner side of the optic axes, *i. e.*, on the nasal side. Therefore, when the lines of vision are parallel the axes of the cornea diverge. Further, they are not both situated on the same horizontal plane; but the difference in this respect is slight, and being of no importance in these researches, may be overlooked.

If we admit the dioptric system of the eye as having a centre, which, as a general rule, it pretty nearly has, then the line of vision and the axis of the cornea intersect each other at the common optic centre We will designate by α, the angle at which they intersect. It lies at the inner side

of the axis of vision. It was Senff who discovered the small divergence which exists between the axis of the cornea and the line of vision. Helmholtz found in three eyes the angle α to be equal 4° 19′; 6° 43′; and 7° 35′. Knapp obtained almost the same results. I also confirmed these statements, employing two different methods to do so; at first I tried Knapp's method,[5] which, I believe, was borrowed from Helmholtz. It consists in determining the radius of the curve, both of the line of vision and of a fixed number of degrees at its inner and outer sides. Another method has been employed by Dr. Doyer and myself. It presupposes that which is proved by the results obtained by Helmholtz, Knapp, and myself, viz., that the axis of the cornea cuts exactly the centre of that membrane. The angle α is found by determining the angle at which the line of vision and the axis of the ophthalmometer must be inclined, in order that the reflection of a flame, placed in this axis, may fall exactly on the centre of the cornea; the reflected image is so placed when its double images touch simultaneously the edge of each of the double images of the cornea which is opposite to it. In more than fifty eyes, almost emmetropic, I have found, in this way, that the line of vision always cuts the cornea on the nasal side of its axis. More precise observations made on fifteen emmetropic eyes have given to α a maximum value 7°, and a minimum of 3° 5′, the mean being 5° 028′.

From which it follows that in vision at infinite distance, the axes of the cornea in the emmetropic eyes diverge $2\times5=10°$.

This condition, however, does not give one the impression of a divergence in the axes, but rather of a parallelism. Apparent diverging strabismus is only detected when the required angle is greater; and when there is an approach to parallelism, we fancy that a converging strabismus exists. The first of these is peculiar to hypermetropia, the second to myopia.

In my researches made according to the first method, it had struck me that in certain very pronounced cases of myopia, the axis of the cornea coincided very nearly with the line of vision, the value of angle α being very small. In examining seventeen eyes by the second method, I found for α as a maximum $5\frac{1}{4}°$, as a minimum, $1\frac{1}{2}°$, the mean a trifle below 2°. In not less than five of these eyes, the value of α being negative, the angle lay on the outer side of the visual axis. In general

[5] Verslagen en mededeelingen van de koninglijke Academie van weetenschappen. D. xi., bl. 159.

the greater the myopia the smaller the angle. For hypermetropic eyes we have remarked precisely the contrary. In sixteen hypermetropic eyes the value of α was found, the minimum to be 6°, the maximum 9°, and the mean 7° 3′. A point worthy of remark, and which proves how constant these relations are, is, that the maximum value of α in myopia is surpassed by the minimum value of that angle in hypermetropia.

The determination of the radius of the curvature of the cornea, both in the line of vision and for a point distant for 10° outside it, gives for myopia a smaller value in the line of vision; for hypermetropia one finds the smaller one outside the line of vision.

Von Graefe[6] has already perceived that it is not rare to find myopia accompanying an apparent converging strabismus. In fact, the difference may be very considerable, according to what has been stated above: a divergence of 10°, belonging to an emmetropic eye, may be replaced by a convergence of 3°, or even of 9°, as I have recently observed. For hypermetropic eyes the deviation is sufficiently pronounced for to be remarked at the first glance of the eye; a divergence of 16° to 18° will never be confounded with parallelism. These differences in the direction of the axes of the cornea are very important in reference to the physiognomy of myopic and hypermetropic people.

So far as myopia is concerned the explanation presents no difficulty; the direction of the line of vision is determined by the two points through which it passes—the yellow spot and common optic centre *k*. According as the myopia increases the optic centre is removed from the retina; and even if the distance between the yellow spot and the prolonged axis of the cornea remained the same, still the angle between the line of vision and the axis of the cornea would diminish on account of the removal of the focal centre; however, this is not of much consideration here.

That there is a more important factor in play follows from this—that the value of the angle not only diminishes but may even become negative. This factor is the unequal distension of the external half of the posterior portion of the globe, in consequence of the development of a posterior staphyloma. It thereby results that the optic nerve is drawn away much more from the axis of the cornea, towards the inner side. Now it is the same for the yellow spot, although this latter, in the meantime, is removed further from the optic nerve, the atrophy of the choroid commonly commencing at the margin of the optic nerve, which is turned

[6] Archiv für Ophthalmologie. Bd. i., 1, S. 110.

towards the yellow spot. The unequal distension of the external segment carries the yellow spot more and more towards the point which corresponds to the axis of the cornea; which it can even pass, the consequence of which is a negative value to α.

The comparative greater value of α in the hypermetropic eye depends, in the first instance, on the smaller distance between the optic centre of the eye and the retina. But it is also necessary to look for the cause in a congenital displacement, outwards, of the yellow spot; I think to the study of development must we principally look for a solution of this point. Everything seems to indicate that the hypermetropic eye must be considered as an incompletely developed organ; and this not only from its structure, but also from the very imperfect manner in which it executes its functions.

I believe that the so-called strabismus incongruus of Johannes Müller,[7] of which the very existence has been a little too carelessly denied, is nothing less than the apparent strabismus of which I have just given the description. It is true that the relations which exist between this deviation, and the anomalies of refraction, were not known to him; and that he has not expressly connected it with the position of the yellow spot; nevertheless, what other affection could he have had in view in expressing himself as follows:—"Besides, this kind of strabismus *is not rare;* but in general *the deviation is but little marked;* often even so much so as to pass unperceived, both eyes being equally capable of a steady gaze, and the sight of both perfect." He adds, that the muscles of the eyes are perfectly sound. Then the definition which Müller gives applies very well to our apparent strabismus. "This strabismus," he says, "is congenital (which is certainly the case so far as the apparent diverging strabismus of hypermetropia is concerned) and incurable. It depends on a difference in the position of the corresponding points of the retina, in the two eyes; so that these subjectively are quite one, but those which are identical in both eyes, belong to different meridians; as, for example, the central point of one of the retinas has not its exact analogue in the centre of the other eye, but at a certain distance from its centre." He is less exact in what concerns myopia, when he adds—"The same difference exists in all the identical parts of the two eyes." He illustrates his views by a figure, from which one might conclude that, in his opinion, the line of vision (his optic axis) and the axis of the cornea (his axis of the eye) were non-coincident in one eye only.

[7] Zur vergleichenden Physiologie des Gesichtssinnes. Leipsig, 1826. S. 230.

Von Graefe has described[8] a very marked case of this nature under the name of "an apparent incongruence of the retinæ, by the anomalous entrance of the optic nerve," the yellow spot at the same time, with the optic nerve was thrown very much on the inner side in one of the eyes. He compares this case with another of true incongruence of the retinæ, in which the yellow spot might be found on the nasal side of the optic nerve in one of the eyes. I cannot conceal the fact that this last case is to me a very problematical one. On account of the imperfect sensibility of the portions of the retina, employed in fixation, another explanation might very easily be given, of which von Graefe has himself thought. If, therefore, I cannot admit that any other forms of incongruence of the retinæ are demonstrated besides those which I have written of under the name of apparent strabismus, I willingly apply to these the express words of von Graefe when he says:— "I might not regard this case as one of incongruence of the retinæ, but as an *unsymmetrical development* of the two halves of the optic bulb."

The hypothesis of de la Hire,[9] already controverted by Jurin and Buffon, but revived, in our days, by Pickford,[10] viz., that convergent strabismus commonly depends on the incongruence of the retinæ, does not, after the researches of von Graefe,[11] deserve to be any further discussed.

[8] Archiv für Ophth. Bd. i., 1, S. 435. Ibid, S. 105. Neither am I convinced by the cases which Dr. Alfred Gräfe gives in his clear and concise work (Klinische Analyse der Motilitätsstörungen des Auges. Berlin, 1858. S. 228). I see that Arlt also considers the existence of strabismus incongruus as problematical (Die Krankheiten des Auges. Band iii., S. 320).

[9] Priestley, Geschichte der Optik, übersetzt von Klugel Leipsig, 1775, S. 408.

[10] Archiv für Physiologsche. Heilkunde, 1842, S. 590.

[11] Von Graefe's important observations on the changes in the projection of the optic axes in strabismus have given origin to numerous treatises on binocular vision, in which Müller's theory of identical points has been controverted. What has been written above is so closely connected with this subject that I cannot refrain from briefly giving my opinion on it.

It is necessary to distinguish between *the projection of the field of vision* and the projection of a point in that field (*vide* Holländische Beitrage z. d. Anatom. and Physiolog., Wissenschaften, 1848, t. 7, p. 105 and Seq.) The projection of the field of vision depends on the position of the eye, and on the direction of the line of vision which we assume to be at command. To what part of the so projected field of vision we further project a certain point is decided by the spot which its image occupies on the retina.

In myopia, the image on the retina is larger than what it would be in an emmetropic eye, the angle being the same, and this in proportion as the distance between the optic

II. ON CONVERGING STRABISMUS.

Experience teaches us that converging strabismus is, in by far the great majority of cases, accompanied by hypermetropia. Out of a hundred and seventy-two cases which we have examined, hypermetropia of the nondiverging eye was proved to exist in a hundred and thirty-three; in nine myopia existed, in five to so high a degree that the form of the extended, and but slightly movable eye-ball allowed of no other position; in thirteen cases a difference in the refraction of both eyes was noticed; in five inflammation was the cause; in at least five paralysis had occurred; thrice the strabismus was complicated with congenital cataract, and twice with nystagmus. From this we see what a prominent position is occupied by hypermetropia, occurring, as it does, in more than seventy-seven per cent. of the cases; and yet, I am convinced, that if we could investigate, indiscriminately, all the cases of converging strabismus which occur among a given population, a still larger proportion of hypermetropia would be found. In the first place cases of but slight converging strabismus present themselves but rarely to the ophthalmic surgeon, and yet these are precisely those in which hypermetropia is the sole cause of

centre and the retina is greater; but, on the other hand, the retinal surface is larger, owing to its extension. In cases where these two factors compensate each other the projected images on the retina might preserve the same size; but in consequence of the disproportionately large dimensions of the posterior pole in very advanced myopia, an object seen by direct vision will be projected smaller than before the extension, *i. e.*, smaller than in a normal eye. Nevertheless, in regarding an object, its size can be correctly estimated, and its limits at once accurately defined by the finger. If the lines of vision be directed one after the other towards the outlines of an object, the change which is made in the relation between the necessary muscular contraction and the projected dimensions of the object are not betrayed by any apparent displacement. When one looks at different objects—through spectacles with concave glasses—alternately by moving the head, such an apparent displacement really takes place; and if this is not observed on moving the eyes, it is to be attributed to the fact that the disturbance of the connexion between the projected size and required motion is compensated for by the deviating direction with which we regard an object through convex or concave glasses.—From what has been said it appears that, in consequence of a displacement taking place gradually, by extension, a point of the retina is projected outwards in a direction different from its original one. Now if this direction can be changed for one and the same retinal element, so as in cases of displacement to preserve its relation with the other means of perception, then it is to be supposed that the direction in question is not a congenital one, but has arisen with the other means of perception.

In the same way, the projection of the whole field of vision may, in abnormal circumstances, be changed. In a certain equipoise of the muscles, an object looked directly at, lies straight before the eyes. If this position be changed—while we

the squint. If inflammation or paralysis exists, or if any peculiar complications present themselves, then the patient does not neglect to seek assistance; and so, proportionally, a larger number of these exceptional cases are observed. In the next place, many cases are registered as "converging strabismus" which ought not to be referred thereto, such as those of recently acquired paralysis of the abductor muscle, and the too strongly converging, almost immovable, myopic eyes, &c.; and lastly, it is more likely that a few ordinary cases have been neglected, than those extraordinary ones, whose pathogeny has not yet been quite cleared up. I do not, therefore, hesitate to declare, that it is quite exceptional, to find converging strabismus without hypermetropia.

It is not with the highest degrees of hypermetropia that strabismus is generally connected. At least in young individuals hypermetropia may be totally latent, having been involuntarily neutralized by an increased effort of accommodation, and appearing only after artificial paralysis of the accommodation. On a former occasion[12] I have mentioned the fact

imagine the same equipoise to continue (for example in paralysis, after section of the inner or outer recti, &c.), we still project the object seen by direct vision as if it was straight before us, although it be placed laterally: therefore the *projection of the field of vision is false*. The consequence of this is, that double images arise in connexion with the other eye, which will be on the same side when the eye is deviated inwards, and crossed when it is turned outwards. If, however, the affected eye be used alternately, which is generally the case in diverging strabismus, it often learns by degrees, to find out the situation of objects, so as to distinguish properly its own impressions from those of the other eye, to project correctly, and to assign a very different position to the two objects, which have their representation respectively in the yellow spot of each eye. The two yellow spots are, therefore, no longer projected towards the same points in space. In this case, even if we employ weak prismatic glasses, correcting only a part of the strabismus, there will exist double images on the same side as the corresponding eyes, of an object whose image falls on the outside of the yellow spot in both eyes.

That this may occur after tenotomy with incomplete effect is shown by a very instructive case reported by Dr. Alfred Gräfe (work cited, p. 236). The reverse may also occur after a long-continued or congenital convergence of one eye inwards.

Herein lies the proof that in the case of an abnormal position of the optic axes each eye can learn for itself how to project its own field of vision in the right direction. Hence it follows that a projection of both fields of vision, the one over the other, may also be acquired, as a consequence of the seeking of corresponding representations in those two portions of the retina, susceptible of the most accurate perceptions, namely, the yellow spots. By projecting their impressions, the one on the other, other portions of the retina also acquire the power of corresponding, which they can lose at any moment, as it is not dependent on a fixed anatomical cause.

[12] Ametropie en hare gevolgen. Utrecht, 1862. Bl. 45. Arch. f. Ophth. Bd. VI., I., S. 92.

that converging strabismus is generally dependent on hypermetropia, and I had imparted these views to many of my colleagues *viva voce*. This induced Dr. Pagenstecher and Dr. Saemisch[13] to turn their attention to this subject, and they inform us that in sixty-two cases of concomitant converging strabismus hypermetropia was found in only twenty-nine. This result I readily accept; they have in reality only detected manifest not latent hypermetropia, and in consequence of this they are themselves convinced, "that slighter degrees of hypermetropia have been certainly overlooked, stronger ones have been under-valued." I see, therefore, in their communication a complete confirmation of my views; for I have not been able myself to directly establish *manifest* hypermetropia in much more than fifty per cent. of the cases.

The most frequently occurring hypermetropia equalled $\frac{1}{30}$, $\frac{1}{10}$, rarely $\frac{1}{7}$ or more. Absolute hypermetropia did not exist in the majority of cases; but it attained in young individuals a considerably higher degree. In manifest hypermetropia of $\frac{1}{30}$, the absolute hypermetropia might be estimated at $\frac{1}{15}$, or something more; when in the cases of a complete absence of manifest hypermetropia, the absolute hypermetropia was estimated during paralysis of accommodation, it still rarely remained under $\frac{1}{15}$.

Since, therefore, hypermetropia as a rule exists in all cases of converging strabismus, no other explanation is conceivable than that hypermetropia is the cause of the squint. It is, at any rate, the primary anomaly in the construction of the eye to be sought for, and is originally peculiar to it. Strabismus is a secondary condition, which only arises some years after birth. In a very early stage, or at the very commencement of the so-called periodical squinting, it can be indisputably proved that hypermetropia is already present, so that it must precede the squinting; and if we add to this that *incipient* squinting immediately begins to disappear if the hypermetropia be neutralized by a proper convex glass, then we must inevitably conclude that it is the hypermetropia that causes the strabismus. The only question remaining is—How can it do this? There is no difficulty in answering this question.

In order to see distinctly, the hypermetropic patient must make great efforts of accommodation; and this while looking at objects at every distance. Even while looking at very remote objects, he must endeavour, by

[13] Klinische Beobachtungen aus der Augenheilanstalt zu Wiesbaden. Erstes Heft. Wiesbaden, 1861.

an effort of accommodation, to overcome the hypermetropia; and in proportion as the object gets nearer, so must he add to this effort that which would be required if the eye were a normal (emmetropic) one, so that looking at near objects requires a great deal of effort. Now, there exists a certain connexion between accommodation aud the convergence of the lines of vision. Thc stronger one can converge the more powerfully can he bring into operation his faculty of accommodation. A certain tendency to increased convergence cannot be, therefore, altogether absent in the case of any exertion of the accommodation. This tendency exists in every hypermetropic eye. One can be easily convinced of this by holding negative glasses before emmetropic eyes, and bringing them thereby into a hypermetropic condition. It will then be found that, at each effort to see distinctly, double images threaten simultaneously to present themselves, and that there is, in short, only the choice between indistinct vision and squinting: this conflict probably existed in all hypermetropic eyes, without their being conscious of it.

Hypermetropia is a very widely diffused anomaly. I am persuaded that it occurs still more frequently than myopia. If then converging strabismus be, as a rule, a consequence of hypermetropia, it is evident that hypermetropia very frequently exists without causing squint. One might even say that strabismus develops itself but in a comparatively very small number of cases of hypermetropia. This need, however, by no means surprise us. In fact, the desire to see an object, simply with both eyes, at the same moment, makes itself, as a general rule, energetically felt; the direction of the lines of vision is thereby strongly marked. Many years ago I convinced myself of this fact by my experiments on the effects of prismatic glasses.[14] If we place before a normal eye a weak prismatic glass, with the refracting edge turned inwards, then looking at a fixed object, it at first appears double; but then an increased convergence is at once and involuntarily called into play, which causes an union of the double images; if, in a moment or two, we now remove the glass, double images again make their appearance, and as speedily, through a diminution of the convergence, disappear, coalescing, so to speak, of themselves. The movements here alluded to take place, in fact, so spontaneously, that the person is not even conscious of it. This aversion to double images, or rather this instinctive clinging to single binocular vision, preserves the hypermetropic eyes of most people from squinting, they preferring rather to sacrifice pleasant, easy, and sharp vision than

[14] Nederlansch Lancet, 2 Ser, D. III., bl. 233. 'S. Hage, 1845.

to suffer different objects to pourtray their images on the two yellow spots.

We herein discover the reason why the majority of hypermetropic eyes do not squint. Let any person with hypermetropic eyes cover one eye with his own hand, both eyes, however, being open, and in most cases th line of vision of the covered eye will, very soon deviate inwards. The same thing will happen if a negative glass is held before a normal uncovered eye. The question which now naturally arises is, what circumstances, in the case of hypermetropic people, must co-operate to cause the existence of squint? They are of two kinds—*first*, A, those which diminish the value of binocular vision, and *secondly*, B, those which facilitate convergence.

A. To the first belong—

I. *A Congenital Difference in the Visual Power, or in the Refraction of the Two Eyes.*—In hypermetropic people, sharpness of sight is often deficient in one or both eyes. This is partly to be ascribed to astigmatism, partly to an imperfection of the retina, as yet unaccounted for. If one eye is affected, then the image in this eye will not, in the case of too great convergence, be very troublesome.

The same is the case when the degree of hypermetropia is rather high in the one eye, and the image in this eye is consequently less distinct. In both these cases strabismus is most likely to develop itself; but the disposition is greatly increased, when, as is often the case, both circumstances are united in the one eye, viz., diminished sharpness of vision, and a high degree of hypermetropia. If the eye has been long in a state of squint, then, as a consequence of the strabismus, a secondary diminution of sharp-sightedness has arisen, to which we shall hereafter refer. Even then, however, a high degree of hypermetropia can, with the help of the ophthalmoscope, be proved to exist.

II. *Spots on the Cornea.*—It is often observed in strabismus that the squinting eye, or indeed both eyes, exhibit opacities or spots on the cornea. Very recently Pagenstecher and Saemisch directed attention to this frequent occurrence of spots on the cornea in cases of strabismus. It does not, however, appear to me likely, that spots on the cornea would of themselves alone be sufficient to cause strabismus. Even if the image in the unaffected eye should be less perfect, still experience teaches us, that even then the preference is given to binocular vision; and it is not very easy to comprehend how that one of the eyes should be disposed to diverge solely for the purpose of allowing a totally different picture to fall on its yellow spot, rather than allow a picture, slightly different, it is

true, but of the same kind, to do so. Ruete[15] has, on good grounds, decided, in this way, the controversy between Beer and Joh. Mueller. It is, however, quite another matter, whether, supposing hypermetropia to be present, spots on the cornea, or other opacities, will not increase the tendency to strabismus; and whether the great indistinctness of the image will not render the diplopia less disturbing, as well as diminish that aversion to it, which is the great safeguard against strabismus. This I am very much disposed to believe; at least I find corneal spots in hypermetropic patients with strabismus very much more frequently than in those without it. It is true that there may still exist another connexion between strabismus and spots on the cornea, to which allusion has been already made by Ruete.[16] An inflammation, for example, the cause of the corneal spots, may, at certain stages, extend to some of the muscles, and bring on, in the first place, a spasmodic and then an organic contraction of the muscular tissue. I myself have already recorded such cases. They are, however, comparatively rare, and are of but small importance in accounting for the preponderance of spots on the cornea in hypermetropia, accompanied by strabismus.

B. To the second belong—

I. *Peculiarities of Form or Innervation of the Muscles, hence Easy Motion of the Eyes Inwards.*—A congenital insufficiency of the recti interni muscles not unfrequently occurs. It is easy to believe that the reverse may also occur; and, indeed, many eyes can converge, without any great effort, as much as 3″, or even 2″ and 1″·5 from the eye. It may be presumed that the shape and position of the globe, as well as the structure and innervation of the muscles, exercises a great influence on the amount of convergence possible.

While insufficiency of motion inwards is a preservative against converging strabismus, a great increase of mobility in this direction will increase the tendency to this form of squint. By many it can be easily produced, in a high degree, by an exercise of the will; by others not at all, or only with the greatest difficulty; and if it be said that such voluntary squinting, frequently repeated by a desire to imitate, or from a habit of mocking, has given rise in some persons to a permanent squint, I readily grant it, on condition that, at the same time, hypermetropia existed. Moreover, I have never been able to convince myself that a

[15] Lehrbuch der Ophthalm. für Aerzte und Studirende B. II., S. 520. Braunschweig, 1854.

[16] L. c. p. 537.

particular disposition to strabismus was hereditary; but in this I wish to be properly understood. Hypermetropia is, to a very great extent, inherited; it is rare, in cases where the eyes are hypermetropic, not to find hypermetropia present in one or other of the parents, and also in some of the other children; but whether this hypermetropia be complicated or not with strabismus in the parents, has, at all events, a very slight influence, if any, in the development of the same anomaly in their hypermetropic children. If there exist in a family a case of converging strabismus, we may be almost sure that hypermetropia is present in some other of the members; but it has seldom fallen under my notice to find the majority of the hypermetropic eyes in the same family squinting.

II. *The Relation between the Line of Vision and the Axis of the Cornea.*— We have seen above that in the case of hypermetropic patients in general a more than ordinary divergence of the corneal axes is required, in order to give a parallel direction to the lines of vision, whence apparent diverging strabismus arises in so many hypermetropic patients. On the other hand, we know that the majority of eyes are only with difficulty brought to diverge; a weak prism held before the eye, with the refracting angle outwards, is sufficient to produce double images, which most people are unable to overcome by a divergence of the lines of vision. Even for the sake of single vision, many cannot succeed in diverging their eyes a few degrees. It may, therefore, be easily taken for granted that when, for simple vision, a more than ordinary divergence of the optic axes is required, such divergence will not be very easily effected. This takes for granted, that in looking at near objects it will be easy to converge too much. The causes that were treated of in Section I. promote convergence in an absolute manner. The connexion between the line of vision and the axis of the cornea, in hypermetropic people, has relatively the same result. Now if, on looking at a greater distance, the divergence of the corneal axes remains often too feeble; then, on looking at a near object, under the influence of hypermetropia, the convergence will be relatively too great. The conditions requisite for the development of strabismus are thus obtained. I have often, in reality, observed, that in squinters, after tenotomy, a considerable divergence of the corneal axes was requisite to make the lines of vision take a parallel direction. Often the eyes are apparently perfectly well directed; and still it will be remarked that, on looking at a distant point alternately with either eye, covering the other eye with the hand, the opened eye must still make each

time a slight movement outwards, in order to fix the distant object. Sometimes this is the case in so high a degree, that for binocular vision at a distance, a disfiguring divergence is requisite. This led me to conjecture whether, since in general the large value of the angle α in hypermetropia promotes the existence of strabismus, an unusual largeness of this angle might not predispose, in a special manner, to it also. In order to verify this conjecture the angle α was measured in ten cases of converging strabismus. The measures were taken, for the most part, acccording to the method described above, by our assistant Mr. Hamer, with an exactitude which is peculiar to him. The following table, contains the results:—

TABLE I.

Persons	Sex	Age	Deviation	Eye	Refraction Hm.	Refraction H.	A.	S	Remarks
1	m	23	Str. c. Od.	Od.	$\frac{1}{10}$?	$\frac{1}{8}$	5°·8	0·2	
				Os.	$\frac{1}{28}$	?	6°·5	0·67	
2	m	15	Str. c. Os.	Od.	$\frac{1}{12}$	?	6°	1·	
				Os.	$\frac{1}{12}$	?	7°	0·28	
3	f	25	Str. c. Od.	Od.	?	?	6°·75	0·1	
				Os.	$\frac{1}{40}$	?	6°·5	0·85	
4	m	16	Str. c. Od.	Od.	?	?	?	0·01	Could not fix
				Os.	in H $\frac{1}{28}$? in V $\frac{1}{30}$	in H $\frac{1}{12}$ in V $\frac{1}{24}$	7°	0·45	
5	f	23	Str. c. Od.	Od.	in H ? in V ?	in H $\frac{1}{24}$? in V $\frac{1}{40}$?	8°	0·2	As.
				Os.	$\frac{1}{20}$?	in H $\frac{1}{11}$ in V $\frac{1}{16}$	7°	0·5	As.=$\frac{1}{35}$
6	m	12	Str. c. altern.	Od.	? ?	in H $\frac{1}{16}$ in V $\frac{1}{18}$	7°·5	0·4	As.=$\frac{1}{16}$
				Os.	? ?	in H $\frac{1}{10}$ in V $\frac{1}{20}$	8°	0·25	As.=$\frac{1}{20}$
7	m	19	Str. c. altern.	Od.	$\frac{1}{12}$	$\frac{1}{6}$	8°·5	0·66	
				Os.	$\frac{1}{16}$	?	7°	1·	
8	m	22	Str. c. Os.	Od.	$\frac{1}{11}$	$\frac{1}{6}$	9°	1·	Str. disappeared on dilatation of pupil Od.
				Os.	$\frac{1}{10}$	?	7°·5	0·41	
9	f	18	Str. c. Od.	Od.	$\frac{1}{20}$?	?	?	0·025	Could not fix
				Os.	$\frac{1}{24}$	?	9°	0·4	
10	f	16	Str. c. altern.	Od.	$\frac{1}{18}$	?	10°·1	1·	
				Os.	$\frac{1}{16}$	?	9°	1·	

Hm. signifies Hypermetropia manifesta.
H. signifies Hypermetropia totalis, after instillation of atropine.
A. signifies the angle between the line of vision and the axis of the cornea.
S. signifies the sharpness of vision.
Str. c. Od. signifies Strabismus convergens oculi dextri.
Str. c. Os. signifies Strabismus convergens oculi sinistri.
Str. c. altern. signifies Strabismus convergens alternans.
As. signifies Astigmatismus.
in H. signifies in the meridian of the minimum of the curve (as a rule horizontal).
in V. signifies in the meridian of the maximum of the curve (as a rule vertical).
? signifies not at all, or not accurately determined.

In case No. 8 there existed a permanent strabismus which, wonderful to relate, disappeared during the time when the pupil of the sharp-seeing right eye was dilated. The left eye then assumed a correct position, without there being any deviation of the right.

This table again shows what had been before manifest, viz., that as a rule the angle α for both eyes of the same individual is pretty nearly the same. For this reason, in the cases of No. 4, Od. and No. 9, Od., which in consequence of impaired vision did not fix, we in calculating the mean value for both eyes assumed that $\alpha = \alpha$ of the left eye. As mean we then obtained $\alpha = 7°{\cdot}63$. This exceeds, by but a very little, the mean of $\alpha = 7°{\cdot}3$ in non-squinting hypermetropic people; but here in order to give a prominent place to the influence on the position of the centre of motion, particularly high degrees of hypermetropia were purposely selected, for which cause also the value of α is increased. In order to obtain, therefore, a better basis for comparison, the value of α was, moreover, determined in some cases of hypermetropic people, whose degree of hypermetropia was about the same that we meet with among squinters. The results are to be found in the following table:—

TABLE II.

Persons	Sex	Age	Eye	Refraction			A.	S.	Observations
				Hm.	H.	H?			
1	m	19	Od.	$\frac{1}{20}$	?	$\frac{1}{14}$	4°·5	0·85	Astig?
			Os.	$\frac{1}{28}$	$\frac{1}{16}$	$\frac{1}{16}$	3°·6	0·85	Astig?
2	f	50	Od.	$\frac{1}{12}$	?	$\frac{1}{13}$	5°	?	
			Os.	$\frac{1}{12}$	?	$\frac{1}{13}$	5°	?	
3	m	55	Od.	$\frac{1}{12}$	?	$\frac{1}{12}$	5°	?	
			Os.	$\frac{1}{12}$	?	$\frac{1}{12}$	5°	?	
4	m	60	Od.	$\frac{1}{28}$	?	$\frac{1}{60}$	5°·75	1·	
			Os.	$\frac{1}{26}$	?	$\frac{1}{50}$	5°·5	0·95	
5	f	21	Od.	$\frac{1}{36}$	?	$\frac{1}{12}$	6°·25	1·	
			Os.	$\frac{1}{36}$	?	$\frac{1}{12}$	5°·9	1·	
6	m	9	Od.	$\frac{1}{12}$	?	$\frac{1}{6}$	6°·5	?	
			Os.	$\frac{1}{12}$	?	$\frac{1}{6}$	6°	?	
7	m	14	Od.	$\frac{1}{16}$	$\frac{1}{6}$	$\frac{1}{6}$	7°	0·4	Astig.
			Os.	$\frac{1}{20}$	$\frac{1}{6}$	$\frac{1}{6}$	6°	0·32	Astig.
8	m	62	Od.	$\frac{1}{6}$	?	$\frac{1}{7}$	7°	0·25	
			Os.	$\frac{1}{6}$	?	$\frac{1}{7}$	7°	0·25	
9	f	13	Od.	$\frac{1}{24}$	?	$\frac{1}{7}$	8°·5	1·	
			Os.	$\frac{1}{20}$	?	$\frac{1}{6}$	8°·75	1·	
10	m	36	Od.	$\frac{1}{24}$	?	$\frac{1}{11}$	8°·8	1·	
			Os.	$\frac{1}{24}$	?	$\frac{1}{11}$	9°·2	1·	
11	m	21	Od.	$\frac{1}{10}$	?	$\frac{1}{6}$	9°	0·9	
			Os.	$\frac{1}{10}$	?	$\frac{1}{6}$	9°	0·9	

The column marked H? gives the total hypermetropia as it has been valued in young individuals.

In the first place, then, we find, in these non-squinting hypermetropic people that the angle α has a mean value of 6°·56, viz., 1°·7 less than in those with squint; secondly, it is very evident that the degree of hypermetropia has some influence on the angle α. The comparison of the value of this angle, with its ascertained mean value in high degrees of hypermetropia, viz., 7°·3, is sufficient to show this; but it appears still more distinctly in Table, II., where the individuals are arranged according to the magnitude of α; and from column H?, wherein the probable degree of hypermetropia at fourteen years of age has been estimated. It immediately strikes one that the latter keeps pace pretty evenly with α. In estimating H? I used, with the due allowance for age, the already known Hm., and sometimes also H; the results can differ but very little from the real value.

The result then is that in equal degrees of hypermetropia, a high value of the angle α predisposes more particularly to strabismus. To this result I attach more than ordinary importance, because it is thereby proved, that the angle α, of greater value in hypermetropic people, cannot, as a general rule, be neglected when one studies the connexion that exists between hypermetropia and converging strabismus.

In the most developed forms of hypermetropia, strabismus is seldom observed; this need not surprise us. In them we have the faculty of accommodation insufficient (even in cases of abnormally increased convergence) to produce perfect images, and consequently one is much more likely to adopt the plan of gaining correct ideas from imperfect representations than to improve these by a maximum of effort. We have seen above that strabismus is chiefly found in moderate degrees of hypermetropia These cases belong to relative hypermetropia. The eye can adapt itself for parallel and even for diverging rays, and can even preserve the accommodation for some time, but only by means of a convergence of the lines of vision on a point situated nearer to the eye than that from which the rays proceed. The minimum of hypermetropia at which strabismus begins, depends, without doubt, partly on the value of angle α, and partly on the extent of accommodation. The smaller the latter, and the larger the former—the smaller will be the degree of hypermetropia necessary to produce squint; but the diminution or total loss of accommodation no more brings on strabismus than the feebleness of accommodation, the consequence of advancing years, does.

With regard to external causes, we often hear mentioned the fixing of the eyes on near objects, particularly those having an oblique direction,

such, for example, as a feather in the nurse's cap, the flame of a candle, and so on. It will by this be sufficiently evident, that I attach but little importance to these notions; at least, I am persuaded that the emmetropic eye will never, by such means, be taught to squint. However, I would not assert so positively, that in the hypermetropic eye there would be no danger in such things—the fixing of the eye on objects having an oblique direction might especially exercise some influence on it. In such cases it often happens that the point fixed on may be seen by but one eye, whilst the field of vision of the other is limited by the nose; and when the one eye only sees an object then the second eye misses a guide to direct its movements, and there is, therefore, nothing to hinder it, if hypermetropic, from converging too strongly in order to see distinctly. It cannot, I think, be denied, that in this way the rectus internus might acquire a certain preponderance which would pave the way for a further development of strabismus.

I have already observed that squinting varies both in kind and in form, according to its etiology and according to the affection of which it is the result, and with which it makes its appearance as a pathological whole. This applies, in every respect, to strabismus, the consequence of hypermetropia. Since, then, this form of converging strabismus is the most common—the typical form one might say—it is very natural that what has been written on strabismus in general should answer here. Let me be allowed to give a brief sketch of it; and in doing so I shall be obliged to mention many well known facts; but in this way I shall the better find an opportunity of adding some further remarks on the nature, symptoms, and pathogeny, of this affection.

Converging strabismus, the result of hypermetropia, seems, for the most part, to manifest itself about the fifth year, probably because the effort to acquire a sharp distinct vision commences then to develop itself; moreover, the accommodation is then sufficiently strong to overcome the hypermetropia, by a somewhat increased convergence, with ease. Little faith, as a rule, is to be placed in the stories respecting its appearance at or shortly after birth, in consequence of convulsions or other diseases. As an exception to the above, it is sometimes met with after the seventh, up to the eighteenth, year, without any appreciable cause existing. At first the deviation is transient, being intimately connected with the act of fixing—that is with the effort to acquire distinct vision; sometimes it is only found when the eye is fixed on some near object, disappearing when the stare is over or the eyes are closed. This is the

so-called periodic squinting which, by some, is described as a particular stage. In this stage, even when squinting develops itself for the first time, so late as the sixteenth or eighteenth year, no complaints about double vision are heard. This, in my opinion, is accounted for by the fact that the deviation arises only by reason of an effort to obtain a distinct image of a certain object. The attention is concentrated upon this object; its duplicate lies in the deviating eye outside its yellow spot; and for that reason alone must show itself indistinctly—so that, in presence of the object directly stared at, it is not easily seen as a double image—while on the yellow spot itself there appears the image of some totally different object with which the person has nothing whatever to do, and from which, consequently, he can the more easily abstract himself. Sometimes this form of the so-called periodic squint lasts a very long time; or, as regards the seeing of near objects, even permanently.

Stoeber[17] and Arlt[18] have each described a remarkable case of this kind, the cause of which, however, must have remained unknown to them. Arlt's case is particularly instructive, because in it the squinting was brought on voluntarily in order to guard against the asthenopia which showed itself in binocular vision of near objects. A similar instance came beneath my notice a short time since, in the case of a girl of eleven with hypermetropia $\frac{1}{10}$ of the right and $\frac{1}{10}$ of the left eye; with convex glasses,—$\frac{1}{14}$—strabismus was absent. Such cases sometimes lose subsequently the ability to squint. Convergence is a peculiar form of movement which the will cannot sometimes discover, although its mechanism is very easy. It is not every one who, by turning one eye outwards, can bring the other deep into the inner corner, so as to be, on that account, in a condition to converge strongly. Many people are quite unable to do it. This I have found the case in myopic people, with very slight diverging strabismus, who had for some time given up binocular vision; and I am persuaded, that if they only tried it again more frequently, they would again attain to it. It would, however, bring them no advantage (see "On Strabismus Divergens"). The finding of certain muscles which we are not in the habit of using with a distinct object is often troublesome, but it will succeed if frequently tried. Thus, I can bring into play my frontalis, occipitalis, and several of the muscles of the ear; and I so have seen Professor Horner, of Zurich, contract, by itself, the musculus Horneri,

[17] Annales d'Oculistique. 1855. T. xxxiii., p. 177.

[18] L. c. B. iii., S. 312.

and I have also succeeded in doing the same, although only after two days of fruitless labour. Many people cannot make their eyes converge save for the purpose of seeing binocularly some distinct object; but even such will at last succeed in doing so if they only attempt it frequently. The straining of the muscles in the act of convergence is evidently quite different from that which takes place when the one eye, holding the same position, the other looks outwards. But of this hereafter.

In the majority of instances strabismus ends by becoming habitual. The rule is that one and the same eye always deviates (strabismus simplex). This was already the case when the strabismus was still periodic. If the strabismus alternates in a hypermetropic patient, other causes are frequently at play. The strabismus is generally concomitant; the movements are free; the area of movement is normal save that there is an excessive mobility inwards, and a more limited one outwards in both eyes. The one and the same eye alone deviates; the other is invariably well directed. Notwithstanding the internal recti muscles must be considered as shortened. This shortening, at first dynamic, in the case of constant strabismus becomes organic. It is the consequence of excessive use combined with feebleness of the antagonistic muscles; there is no pathological change present. That both the internal recti muscles are shortened results from the habit of keeping the object intently on the side of the distorted eye, so that even in the normal eye the internal rectus is brought into relatively strong contractions. In this position the hypermetropia of the non-deviating eye is best overcome. Even when squint has become habitual, there is in connexion with fixation a relatively stronger contraction of the internal recti muscles whereby the angle of squint increases; in the case where there is already a large angle of deviation, this will be only in a slight degree, because their increased straining occasions less motion. After tenotomy the increase of convergence in these cases, while regarding some object intently, appears again very strongly. This increasing of convergence in the act of fixation, after a correct position has been obtained by tenotomy, is important from a two-fold point of view. First, because we have adults who declare that they distinctly feel the convergence, and perceive, at the same time, that they induce it, as it were, voluntarily in order to see more distinctly. A more direct proof that hypermetropia may determine strabismus could, I think, not be given, for here we have, in a manner, a return to the first period of strabismus, with this difference—that the deviation can now be appreciated by the

person himself; and, just as in the original stage, the first appearance—so here the relapse must be guarded against by the use of convex glasses sufficient to centralize the hypermetropia. The practical direction to use proper convex glasses while working, after tenotomy, is the second reason why we considered the symptom in question important. In simple strabismus the sharpness of sight becomes, in the affected nerve, more and more enfeebled. At first if the hand is held before the normal eye, the squinting eye directs itself properly towards an object, and may even remain thus fixed when the hand is removed; but it soon, however, gives place to the other, usually when some new motion is attempted, often even at the first winking of the eyelids. Sharpness of sight will now have already diminished in the deviating eye; but it is still, for a considerable length of time, nearly sufficient, and it may, by exercise, be restored; it improves, too, most generally, immediately after tenotomy. In the course of time, however, the deviating eye no longer directs its line of vision on the object when the normal eye is excluded; but this line passes along on the inner side, so that the image of the object falls on the inner side of the retina. When such is the case we may conclude, that the sharpness of sight of the deviating eye in the line of vision, as well as in the common visual field of both eyes is diminished; whilst, on the other hand, that of indirect vision on the innermost portion of the retina, so far as this portion has its own field of vision and sees objects not represented in the retina of the other eye, has remained undiminished.

Von Graefe was the first to investigate this loss of physiological sensibility by psychical abstraction. Truly a remarkable phenomenon! It is a well known fact that we can, by attention, increase the acuteness of our organs of sense. That which precedes proves, on the other hand, that a nerve may lose the power of receiving those impressions from which we desire psychically to abstract ourselves, and presents us, therefore, with a very important example of this fact. In such cases, although no organic changes are to be noticed in the retina, yet, neither by constant practice nor by tenotomy, is there any considerable improvement to be obtained.

Has the origin of strabismus been accounted for on any former occasion by the presence of hypermetropia? This question may, I think, be answered in the negative; indeed it is almost natural that it should be so, because it is only for the last few years that hypermetropia has been understood, and total hypermetropia, and, to a considerable extent, latent

hypermetropia had been overlooked, until that, having convinced myself of their existence, I commenced to perceive their connexion with strabismus. My perceptions have been, without any doubt, assisted by what has been discovered and recorded by my predecessors. Not to speak of some few isolated observations[19] which, since the discovery of hypermetropia, proved it to exist along with strabismus, I would, in the first place, refer to Böhm's[20] investigations respecting squinting, where it is plainly stated that squinters can distinguish a certain type, with the assistance of *convex glasses*, at a greater distance than they would with unassisted vision. This observation was of great importance, and it might have led to the discovery of hypermetropia, and, in particular, of the connexion of hypermetropia with strabismus, had Böhm, with a thorough knowledge of dioptrics, understood and rightly explained the facts which he had observed. Instead, however, of thinking of a condition in which the focal point of the dioptric system should lie behind the retina, Böhm had recourse to a mysterious connexion of "*physical presbyopia*," with "*vital myopia*;" and he was very far, at all events, from seeking in this for the cause of squint. In investigating the origin and cause of strabismus he falls into the same error as all his predecessors—investigating them, not for a distinct form of squint—for a real form of disease—but for a symptom—squinting in general. The causes, resulting from totally different conditions are then sought for and investigated indiscriminately. It might have been forseen that the pathogeny of squint could not in this way be revealed. And further, when Böhm treats of the "*origin of squinting having its source in the eye itself;*" and also, of the "*ætiology of squinting as originating in the eye*," the condition of the deviating eye is, and remains with him, the important matter; he speaks of the "short-sightedness of one eye, while the other preserves its normal condition," of "asthenopia of one eye," of "feebleness of vision of one eye;" and, according to him, it is this eye always that deviates. In this deviation he sees an effort to exclude this eye from vision, without recognising in it an effort to try to improve the distinctness of the images of the undistorted eye. That which we have admitted farther back as one of the circumstances under which the eye more easily allows itself to be withdrawn from binocular vision, is, for him, the all important

[19] Vorgl. de Haas, Geschiedkundig onderzoek omtrent hypermetropie en hare gevolgen, 1862, p. 61.

[20] Böhm, das Schielen. Berlin, 1845. I follow here de Haas almost word for word as he mentions that he has printed this part of his dissertation from my Lectures.

cause of squint. So Böhm was as far from understanding the reason of converging strabismus as any one else.

In later years von Graefe[21] was certainly very nearly discovering the cause of strabismus to be hypermetropia. He did not, however, exactly treat of the pathogeny of squint; and he even apologises when, in passing, a few remarks respecting it escape from his pen. These remarks, however, we regard as well worthy of attention; but, as it did not occur to him to introduce hypermetropia as an element into the subject, they remained, for the most part, fruitless. Von Graefe mentions, as a well-known fact, that an "intercurrent or periodic squint" frequently, if not generally, precedes a permanent one. Further on, he remarks that all cases of intercurrent squint do not pass into permanent squint. So long as this has not taken place, these cases would require some special remarks, from the point of view of operative assistance. For this reason von Graefe mentions them. But he has obviously also felt that the symptoms incident to these cases had a peculiar significance as regards the investigation of their pathogeny; at least, he considers, from a pathogenetic point of view, the three following categories distinguished by himself:—

First Category comprehends those patients whose eyes, while in a state of repose, show no appreciable deviation; but do so the moment they fix them steadily on a certain object, whether it be near or remote. Von Graefe thinks there is a possibility that a cause of disturbance might result to binocular vision from the deviating eye; and that, therefore, its image might be voluntarily deviated. That, in this way, a permanent squint might possible arise is plain—Von Graefe does not, however, consider everything as hereby explained. "If the deviation manifests itself only under certain conditions, for instance, in the case of a vivid perception of the images on the retina, and not where this fails, one must suppose the existence of some link between the act of vision and the muscular movements" (von Graefe, l. c., p. 281); and again—"if this latter is not the disturbance of the images on the retina of either side, then, in the next place, the circumstances of the accommodation present themselves for investigation."

With respect, however, to the first mentioned supposition, von Graefe remarks that the one eye deviates while intently regarding an object at any distance, and even when the hand is placed before it; and whilst it

[21] Archiv. f. Ophthalm. B. iii. Abth. i., S. 277.

did not occur to him, with respect to the last mentioned case, that hypermetropia might account for it, so he knows no other explanation to give save the following somewhat obscure one:—"Every act which has for its aim the exact perception of objects throws on the altered muscle the incentive to abnormal contraction.

Second Category comprehends those cases in which, up to a certain point (eight inches, a foot, four feet), the axes of vision have a normal direction, whilst beyond that distance a striking deviation is manifest. Such cases are generally connected with myopia.

Third Category comprehends cases of which he says "that the pathological convergence appears only in the case of accommodation for near objects. The symptom appears just as well marked when the squinting eye is covered, and must, consequently," he says, "have its origin in the condition of the accommodation, probably in an increase of the resistance of the muscles, accompanying an increased state of the refraction of the eyes. The increase of the tension of the muscles," he continues, "arouses the slumbering impulse to abnormal contraction in the affected muscle."—He further refers to the peculiar cases in which, while looking at near or distant objects, converging strabismus arises; but in which, when looking at objects at a moderate distance binocular vision is preserved. He explains this as partly due to myopia; but frequently both presbyopic and hyperpresbyopic patients belong to this category; myopia in distans sometimes too appeared to exist. He sums up as follows:—"A feeble degree of pathological convergence of the lines of vision, corresponding to the natural tendencies to straining of the muscles, exists, for all and every distance of the object. If the refraction of the eye be augmented, either by bringing the object nearer or holding up a concave glass, then the morbidly increased contraction commences; for moderate or short distances, and relatively large retinal images, the prevailing tendency of the muscles is, in order to preserve single vision, resisted; for a greater distance, the retinal images decreasing in size, this no longer happens, and double images arise which, owing to an abnormal contraction of the muscles, appear at greater distances from each other."

Finally, Alfred Graefe,[22] in a case of intermittent squint—called also, but less correctly, "spastic squint"—asks himself the question whether "It is the circumstances of accommodation which occasion the deviation of the right eye?" and replying to it as follows:—"Certainly not; for it

[22] Klinische Analyse der Motilitätsstörungen des Auges. Berlin, 1858. S. 222.

has been expressly pointed out, at the commencement of this chapter, that the deviation always commences as soon as an object has been steadily looked at, and consequently it is totally independent of the state of accommodation prevailing at the time"—convincingly proves that he did not think of hypermetropia, which itself requires a straining of accommodation while looking at distant objects.

From all this, it is evident that hints were not completely wanting in literature, tending, after the slighter degrees of hypermetropia were detected, to connect it with strabismus.

III. DIVERGING STRABISMUS.

Diverging strabismus depends, as a general rule, on myopia. At the commencement of my statistical researches I was already aware of the relations which existed between hypermetropia and converging strabismus; but I was very far from supposing that there was at all the same intimate connexion between diverging strabismus and myopia. It was systematic investigations alone that brought this fact first to light.

The nature of the relation is not altogether the same in both cases. If hypermetropia determines the converging squint, it is because the anomaly of refraction requires great efforts of accommodation. When diverging strabismus arises in connexion with myopia, then the anomaly of refraction as such, is not altogether without direct influence, but the chief cause of the deviation depends on the distension and change of form of the globe of the eye. When myopia exceptionally occurs, owing to a flattening of the cornea, strabismus is not to be looked for. Since Arlt[23] demonstrated, by anatomical researches, that ordinary myopia depends on the extension of the membranes of the posterior portion of the globe, and the lengthening thereby of the optic axis, this important fact has been generally admitted as correct. All the diameters of the globe are increased in myopia, but especially that which corresponds to the optic axis; it follows that the globe has a tendency to take the form of an ellipsoid, of which the major axis is the optic axis. These large diameters may diminish the mobility of the eye in general; this is especially caused by the ellipsoidal form, which opposes a much greater resistance to its rotation on its minor axes in the interior of a cavity of the same shape, because this demands a change of form. The centre of motion is not only at a distance from the anterior, but also from the posterior pole of the eye; its position is not very unfavourable.

[23] L. c., B. III., S. 237.

The researches which I made conjointly with Dr. Doyer, establish that the centre of motion is situated behind the centre of the optic axis, so that the portion of this axis situated in front of the centre of rotation is to that behind, as 15 : 11. (*Vide* the annexed table given from the French.)

TABLE of the mean obtained by the examination of 19 emmetropic eyes.

19 myopic eyes, M = 1 : 16 up to M = 1 : 2·25
12 emmetropic eyes, H = 1 : 16 „ H = 1 : 3·75

	Mean length of the visual axis	Situation of centre of motion				Angle α between the axis of cornea and line of vision
		Behind the cornea	In front on the posterior of the sclerotic	Proportion per cent.	Behind the middle of the visual axis	
	Millimètres	Millimètres			Millimètres	
E	23·53	13·54	9·99	= 57·54 : 42·46	1·77	5°·082
M	25·55	14·52	11·03	= 56·83 : 43·17	1·75	2°
H	22·10	13·22	8·88	= 59·8 : 40·2	2·17	7°·55

About the same proportions, however, were also found in the case of the longer axes of myopic people; here, consequently, the centre of motion lies further away from the posterior surface of the sclerotic. The excursions are therefore, in these cases, for equal degrees of rotation larger, and the movements necessarily limited; this limitation would be still greater were not the entrance of the optic nerve, on account of the disproportionate extension of the external posterior portion of the segment, moved further inwards, and thus removed considerably less from the centre of motion. To this limitation, moreover, the greater distance between the centre of motion and the insertion of the muscles may help to contribute, to which distance, the arc of rotation, obtained with a given shortening of the muscles, stands in inverse proportion.

Apart from the consideration of all this, the elongation of the axis of the eye gives of itself a sufficient explanation of the diminution of the movements of the globe; this latter affects the movements inwards as well as outwards. With myopic people it is so general that out of seventeen eyes examined, nine could not turn themselves sufficiently far so as to bring, without modification, our method for ascertaining the centre of motion, into use—a method which requires an excursion of not more

than 28° inwards and outwards. Diminished outward motion of the eye is primarily of no further consequence than that the lateral excursions of the eye, for binocular vision at a distance, are smaller, and that to obtain it, assistance, by turning the head, must be sought, a thing which is, however, always necessary when spectacles are worn; but insufficiency of motion inwards has other and more important consequences which we must consider consecutively, so as finally to see absolute diverging strabismus appearing as its ultimate result.

We take it for granted that there is an insufficiency of motion inwards, when the lines of vision cannot be brought to intersect at a distance of 2″·5, at which they cut one another at an angle of about 51°. In high degrees of myopia this insufficiency pretty nearly always exists, and to account for this a two-fold reason may be given. In the first place, the mobility is in reality impaired in consequence of the extension and altered form of the globe, and consequently the insufficiency may be considered absolute; but, in the second place, in consequence of the smallness of the angle α the axes of the cornea must, in order to make the lines of vision intersect, in the distance of 2″·5, be made to converge still stronger than in the case of emmetropic eyes; hence we see that motion inwards must be at least relatively, if not absolutely, confined.

The insufficiency of which we are here speaking leads, in some cases, to wearisomeness of vision, when the nature of the work requires for a lengthened period a certain amount of convergence (asthenopia muscularis).

I have met with some cases in which, in the first instance, vision was binocular; but when the one eye became fatigued it deviated, and then the vision could be continued with facility; others in which this deviating was felt as an annoyance, and gave rise to complaints. I found this latter occur when the degree of myopia was comparatively small, and where, in addition to the muscular resistance of the eye, a certain weakness of the muscles (not merely insufficiency of motion, but actual insufficiency of the internal recti), had to be assumed, a condition which I have observed to be hereditary in cases of moderate degrees of myopia with the beforementioned symptoms. This deviation, produced by the continuous effort to enjoy binocular vision, is the first degree of relative diverging strabismus. The lines of vision intersect each other normally for great distances, but for objects close at hand one eye only is used.

Relative diverging strabismus is here considered as a consequence, and, in some measure, as a further development of the insufficiency of motion

inwards; this is true up to a certain point. If we try, however, to define this relative squinting, it then appears that it is inseparable from high degrees of myopia; and that even if, in such cases, motion was not limited, the squint would nevertheless be present. Relative diverging strabismus takes place, in fact, when the close proximity of an object which one wishes to see distinctly, excludes binocular vision; it consequently makes its appearance, even in cases of unlimited convergence, the moment that the farthest point of distant vision lies nearer the eye than the point which can be reached by the strongest convergence. In this sense, when the myopia for example is greater than $\frac{1}{2 \cdot 5}$ relative diverging strabismus is necessarily present, one eye is certainly (cases of converging strabismus excepted), if the person at the time sees distinctly without glasses, always directed outwards.

From what has been stated it will be seen that relative diverging strabismus may arise, on the one hand, in cases of considerable insufficiency of the internal recti, myopia being completely absent; and, on the other hand, in cases of high degrees of myopia, without any insufficiency of the muscles. The fact is, it occurs in its most important forms, when myopia and insufficiency of the muscles are both present in a moderate degree. Myopia may be considered as the starting point. If it be wanting the muscular insufficiency will only lead to muscular asthenopia, and will seldom develop itself into diverging strabismus. If myopia be present, then a number of circumstances conjoin to bring on relative diverging strabismus, and by this very means prevent muscular asthenopia.[24] The explanation is simple, and has already been given when treating of muscular insufficiency; myopia requires a greater convergence of the lines of vision, because the object of sight lies nearer the eye, and it is exactly in myopia that convergence is, for two reasons, more difficult: first, because of impeded motion, and secondly, because of the altered direction of the line of vision (the smaller angle α). That relative diverging strabismus chiefly occurs in cases of myopia is herewith explained; to this must be added, that the want of binocular vision and the aversion to double images furnish, in this instance, no considerable counterpoise. It is

[24] Thus we read also in von Graefe (Archiv. für Ophth., B. VIII. S. 343):—"We have already mentioned above that myopia furnishes indeed an important, but not an absolutely preponderating contingent (to muscular asthenopia). The latter would doubtless be the case if those patients affected in a high degree by myopia did not pass much more quickly from the asthenopic condition into diverging strabismus than either hypermetropic or emmetropic ones.

generally some small object that a myopic person wishes to see distinctly; this object he brings close to one eye, while the other eye is directed towards some remote object which, in consequence of the myopia, present very diffuse, and hence, only slightly disturbing images. If the act of vision occurs with one eye turned aside, then so much the less will there be a strong tendency to convergence, because then the distance of R (the far point of distinct vision) at once becomes smaller, and the object must consequently be held still closer to the eye. It is precisely in cases of difficult convergence that the combined efforts of accommodation become particularly great.

In progressive myopia we often see how that binocular vision tries to maintain itself in opposition to relative diverging strabismus; but the fatigue which is always increased by the exertion, causes it for the most part constantly to succumb. Reading, for example, commences binocularly; but after a little, one eye turns away, involuntarily and unconsciously, so that one is told that one page shifts itself over on the other; numerous transitions may be proved. If an object be brought closer and closer to the eyes, then the convergence increases almost to its maximum; and if the object remain so, then the one eye turns off the more quickly in proportion as the object was brought nearer to the maximum of convergence. This will equally occur in cases of strong convergence, when the one eye is covered with the hand; and, if the covering hand be removed, the convergence nevertheless continues. Even when the object is brought close to the one eye, whilst the other, still kept open, is covered with the hand, a sufficient convergence is but rarely effected; the effort to maintain binocular vision, begun at greater distances, was the condition on which the convergence was effected. It is not to be found even in the case of a relative diverging strabismus which has become permanent. As an instance of a transition to this latter, it is observed that when the eye is fatigued, convergence is absent, but shows itself whenever it is restored by repose.

Between periodic and permanent diverging strabismus there exists still another condition of some practical importance to which I have already called attention.[25] In it there still exists a tendency to convergence, this is seen by approaching an object near the eye; but before the farthest point of distinct vision is as yet reached, or at the least very soon after, the one eye turns away. In such a case, by the assistance

[25] Archiv. für Ophth., B. viii., Abth. I., S. 83.

of a concave glass, the object is once more seen with both eyes; frequently, however, complaints of fatigue coming on will now be heard; and experience teaches to look for its cause, not in the effort of accommodation, but in the requisite convergence, even if this be comparatively slight; consequently muscular asthenopia is in existence; and here, in order to make binocular vision possible, the combination of prismatic with the concave glasses becomes necessary. In such cases it is particularly obvious that we must seek for the cause of the relative diverging strabismus in the impeded motion inwards, whilst the tendency to use both retinæ for the sake of binocular vision may continue undisturbed. It is only in the case of an absolute diverging strabismus that this tendency, as will appear, is not unfrequently lost.

We have seen above, that in progressive myopia binocular vision of near objects, can only with great difficulty be retained. There are, however, exceptions. According to von Graefe—"an energetic co-operation of the internal recti is consequent on relative myopia;" he even goes so far as to assert, that it is to be regarded as a *pathological condition* "when the contractibility of the internal recti does not progress harmoniously with the increase of the refraction (myopia)." [26]

Indeed, even in cases of high degrees of myopia, whether in consequence of a favourable size of the globe of the eye, or in consequence of an original or acquired preponderance of the internal recti muscles; the lines of vision may sometimes, while looking at near objects, be correctly placed, and may, without much effort, be kept in that direction. This mostly happens at the expense of mobility outwards. A limitation of mobility is, in such a case, never wanting, and it may reach such a degree, that in looking at distant objects the lines of vision cannot be brought into a parallel direction; relative converging strabismus will now present itself. The cases mentioned at page 9 have had their origin alluded to; even in these cases convergence is not sufficient, and then the strange combination arises of relative diverging strabismus while looking at near objects, and of relative converging while looking at those which are distant; whilst looking at moderately distant objects binocular vision is retained. This reminds one of the combination of myopia with presbyopia; all such cases, however, are exceptional. The rule is, that facility of convergence does not keep even pace with the development of the myopia, and that, in a very short time, the tendency to

[26] Archiv. für Ophthalm., B. III., Abth. 1, S. 309.

relative diverging strabismus becomes perceptible. I convinced myself, by investigations, that in myopia, if it commences with parallelism of the lines of vision; mobility inwards is generally, in the majority of cases, diminished,[27] whilst the mobility outward suffers no diminution whatever; nay more, the lines of vision, under the influence of a prism, can usually be brought to a greater divergence than in the case of non-myopic people. It would appear as if convergence was easier on the part of myopic people, since with them, according to my determination of the relative extent of accommodation, certain degrees of convergence are possible, without a proportionate effort of accommodation; herein, however, there is no absolute proof. We should simply learn from this, that by practice, the movements of accommodation can isolate themselves to a certain extent from the efforts of convergence, and make themselves apparent only in cases of high degrees of myopia.

Absolute diverging strabismus is characterized by divergence of the lines of vision when viewing distant objects. While looking at objects close at hand, the divergence sometimes remains unchanged; sometimes it diminishes, or even gives place to a convergence of the eyes, this not being sufficient however; binocular vision is, in such cases, destroyed. I have observed in a few instances, that while looking at very distant objects, divergence existed, but that while regarding objects only a few feet or inches distant, this gave way to a sufficient convergence, which, however, could not be long retained. The fact is one worthy of notice; it may be explained by the circumstance that binocular vision is of much greater importance in judging of near than of distant objects. At first diverging strabismus is generally but little marked, and it increases but slowly; sometimes it will continue but slightly marked throughout one's whole life. It has appeared to me as if there was another origin, in addition to myopia, for the higher degrees of strabismus.

It is only the more absolute forms of diverging strabismus which are designated by the name squint; in this sense it is much less oftener met with than converging strabismus. Now, although here, as in converging strabismus, a certain number of cases must be referred to primary

[27] Still more particular inquiries are being instituted in reference to this subject — the mobility of the eyes—the maximum of convergence—the effects produced by prismatic glasses, &c., in their connexion with the axis of the cornea and the line of vision; also the mode of ascertaining the centre of motion for eyes in which the refraction differ, are being ascertained "by fresh investigations of one of our pupils, Mr. Schuerman, candidate in medicine," *added to note in French translation.*

disturbance of the muscles (paralysis, inflammation, contraction, complicated congenital anomalies, &c.; a blind eye frequently also deviates outwards), yet myopia does not occupy the same prominent position as a cause of diverging strabismus, as hypermetropia does in relation to converging strabismus; at the same time, however, myopia is found in about two-thirds of the cases of absolute diverging strabismus. If we add to these cases those of relative diverging strabismus, then the diverging form of squint is quite as frequently met with as the converging, if not even more so, and the extraordinary causes, proceeding originally from affections of the muscles, or from blindness of one eye, retire completely into the back ground, for in at least ninety per cent. of the cases of relative diverging strabismus, myopia is found. It has often been remarked, that while converging strabismus is chiefly to be met with in children, diverging strabismus but rarely occurs until much later in life. The observation is correct; the fact is closely connected with the cause of its existence—*progressive myopia.*

Now, although absolute diverging strabismus is, as a rule, chiefly developed out of relative, yet in by no means every instance does the absolute follow the relative; the reason of this lies in the circumstances we have mentioned; and it seems indeed to be rather the exception. We find here, as in converging strabismus, a similar relation to the cause. Thus as the majority of hypermetropic people remain free from it, so it is also certain that many myopic people will be found with relative diverging strabismus, and yet the absolute form never developed therefrom. Here, then, the question likewise arises—what collateral circumstances operate to produce the true absolutely diverging strabismus?

Perhaps we shall be able to invert the question, if we, in the first place, reflect—why the relative distortion, in general, disposes to the absolute. The result of this examination may be thus formularised.

Relative diverging strabismus determines the formation of different images on the two yellow spots of the retinæ, at least in the case of close vision. The great desire that these impressions should correspond—the struggle for simple binocular vision, must, in general, be thereby very much weakened. A deviation commencing at the first attempt at convergence, at once becomes considerable, whilst the individual simply yields to the muscular impulse; perhaps this occurs, too, in order to remove (however unconsciously), the double images further from each other, or even to exclude the effort of accommodation, which is associated with troublesome

convergence, and thereby remove the limit of distinct vision to a greater distance from the eye. If, for example, in the case of blindness of one eye, the internal recti are no longer strained for the purpose of seeing near objects binocularly, then these muscles, on account of their diminished energy, lose the power of moving sufficiently, and the usual consequence is a diverging strabismus. Now, relative diverging strabismus induces a similar inactivity, the result likewise of impaired energy; these two important factors meet together, viz., slight resistance to double images, and diminished vigour of the internal recti.

It cannot, therefore, appear strange that the movements of these muscles, even in the case of distant vision, soon cease to be efficient. This must still more be the case in myopic people, in whom the angle α is particularly small, and where, consequently, distant vision requires a smaller divergence of the axes of the cornea than in emmetropic eyes. When once the action of the internal recti is weakened, the effort, which must be made, to overcome the tendency to divergence will easily bring the point of farthest distance nearer to the eye, making the images of remote objects on the retinæ thereby more diffuse; so that, instinctively, the effort will either not be made or be discontinued.

The origin of absolute diverging strabismus is hereby satisfactorily explained. Unless I am mistaken, we must now, as I foresaw, invert the question as it was put above; we no longer ask—what are the concomitant circumstances which operate to bring on absolute diverging strabismus, presuming relative diverging strabismus to be already in existence? but we inquire—why it is that every relative diverging strabismus does not lead to absolute strabismus?

In the first place, I would remark, that even absolute diverging strabismus is very commonly met with (as indeed it appears every day more plainly) in cases of a high degree of myopia, much more commonly than is at all imagined. Slight degrees pass by unnoticed, because although in them the lines of vision diverge, yet the axes of the cornea show no particular divergence, sometimes even less than in non-squinting hypermetropic people. It is only when the properly directed eye is covered, that it appears that the line of vision of the other eye was directed too much outwards. I repeat, however, the question—wherefore is it that every relative diverging strabismus is not followed by absolute strabismus?

The cause thereof is partly to be attributed to the tendency to preserve binocular vision; although, in consequence of the relative diverging

strabismus, the desire for the same impressions on the two yellow, and further corresponding spots, has been weakened, yet it has not been destroyed. In some cases it is this desire for binocular sight that alone resists the deviation. In many people the one eye will actually turn outwards behind the covering hand; and when this is removed, again resume its proper position; and, where the deviation does not take place, the application of a weak prismatic glass, with the refracting angle turned towards the nose, will be sufficient to convince us of the struggle to maintain binocular vision. It is only in cases of the highest degree of myopia, in which not even well marked objects form comparable images, that, during this experiment, convergence fails to appear. From this it is manifest that sharp sight is not an absolute condition, even when the wish for single vision is clung to with the very greatest tenacity.

We look, in the next place, for the cause of the absence of absolute strabismus in limited mobility of the eyes; not only the inward, but sometimes also the outward rotation of the large ellipsoidal eyeball of myopic people is obstructed. This obstruction may go on so far that, as we have remarked above, when sharp vision, at a short distance, is required, relative converging may be joined on to relative diverging strabismus. If, however, it does not attain to this degree, it at least prevents an immoderate deviation outwards, especially where the desire to preserve binocular vision assists it.

Then, again, we find, just as in converging strabismus, various propelling and assisting forces opposed to each other; and it is, in fact, difficult to say under what conditions the former acquire the preponderance. Experience, at all events, has not, as yet, made us acquainted therewith.

Without any doubt, however, the following must be taken into account:—1. All those circumstances which facilitate motion outwards. 2. All those that lessen the importance of binocular vision. Among the former we reckon an original preponderance of the external recti; greater displacement of the lines of vision than is usual as a consequence of myopia (unusually small, or even negative value of the angle α); further, a form and superficial position of the eyeball, favourable to outward motion. Among the latter may be reckoned diminished sharpness of vision of one eye, and above all, difference of refraction in the two eyes; this last-mentioned is a factor of great importance. If the difference in refraction is great, one strong, the other emmetropic, or very slightly myopic, then it is, perhaps, the rule that in looking at distant objects

the myopic eye is distorted outwards. These cases furnish a peculiar kind of diverging strabismus, which, most decidedly, deserves to be thoroughly investigated, and specially described. Sometimes, in such cases, the squinting, especially at the commencement, is intermittent, and only shows itself either when the eye is weary, or during certain mental conditions; at other times it can be overcome, although strongly developed, by an effort of the will, particularly while looking, for an instant, at near objects, but not without being speedily followed by a sense of fatigue, and the sight receives no essential advantage thereby. Not unfrequently, also, the one eye is used for looking at distant objects, the other in close vision; each eye, for the most part, projects, and judges rightly, as long as it sees independently; and this, notwithstanding the constant assertion that the same object seen with the one eye, appears larger, and when seen by the other smaller, than it really is. There are still many curious facts to be related on this subject which merits well to be investigated. As to its pathogeny, with which alone, in fact, should we, in this place, be concerned, it is easy to perceive that, in the first place, binocular vision is not, in such cases, of much value; *secondly*, that the double images of ordinary objects (especially in seeing at a distance), are scarcely noticed, and it is consequently easy to abstract oneself from the impression of the strongly myopic eye; *thirdly*, that the limited mobility affects, in this instance, only the one eye, and a relative deviation outwards, must consequently be attended with less inconvenience; and *lastly*, that as soon as a slight exertion of the internal recti is required, in order to prevent divergence of the lines of vision, such exertion will necessarily not be forthcoming, because the slightly myopic or emmetropic eye, which sees objects distinctly at a sufficient distance, loses, in part, this faculty, in consequence of the combined effort of accommodation.

It is known that Buffon was the first to seek to determine the cause of strabismus to be a difference between the two eyes.[28] He has defined this in a manner sufficiently vague, in the following terms:—"Une inégalité de force dans les yeux." There can be little doubt but that by this he wished to express a difference in the state of their refraction; but, in his researches on strabismus, he evidently, more than once, confounds this difference with that of sharpness of sight. He attempts to demonstrate that unequal impressions of the same objects, on the corresponding points

[28] Sur la Cause du Strabisme ou des yeux louches. Mémoires de l'Académie, 1743. Histoire Naturelle, Supplement IV., p. 416. Paris, 1777.

of the two retinæ, are more troublesome than images of objects altogether different (and, under certain circumstances, this may be the case), and that this is the reason why one of the eyes instinctively deviates. Buffon, in so writing, had in view, particularly, I might almost say exclusively, converging strabismus; but, towards the close of his memoir, he speaks of other cases, "where one eye was employed to look at distant, and the other at near objects, and where the one that remained unemployed, deviated, sometimes inwards, sometimes outwards." Moreover, Buffon supposes that to whatever extent the field of accommodation of the two eyes may coincide, even when their limits are partially different, both eyes can receive sharp impressions of the same object, so that the effort of accommodation of each eye, independently of the other, can be regulated according to the distance of the object. On this error a great deal of his demonstration rests.

Joh. Müller, while he admits the fact, is not satisfied with the explanation given by Buffon. He proposes another[29] very remarkable, because he assumes, for the purpose, a disturbance between the convergence and accommodation of the eyes. We do not find in Müller's work any distinction made between presbyopia and hypermetropia; he does not even distinguish whether it is convergent or divergent strabismus which he means to explain; in this way it was not possible to consider the question properly. But we find mention of an experiment which consisted in determining convergent strabismus, by placing a concave glass before one of the eyes, and then making the person regard steadily a fixed object; an experiment which explains those exceptional cases of convergent strabismus in which the correctly directed eye is hypermetropic, whilst the deviating eye is somewhat less hypermetropic; even, perhaps, emmetropic, but originally amblyopic. If Müller had placed negative glasses before both eyes it could not have escaped him but that there was an easily caused deviation inwards, and perhaps, with his penetrating glance, he would have, on the moment, recognised the nature of hypermetropia and its relations to strabismus.

The inequality of any two eyes, with respect to their sharpness of sight, or their refraction, as a case of squint, has been too much regarded by some,[30] too little by others.[31] I think I have proved that this

[29] Vergleichende Physiologie des Ges., S. 228.

[30] Compare Böhm Das Schielen, l. c., and Arlt, Die Krankheiten des Auges, B. III., S. 306., u. f., Prag. 1856.

[31] Compare Reute Lehrbuch der Ophthalmologie, B. II., S. 524.

inequality is not the immediate cause of strabismus, but, that it may become a cause thereof, under the influence of certain determining conditions existing in the non-deviating eye.

The connexion which exists between binocular myopia and diverging strabismus, has not been passed over altogether without notice. Joh. Müller even writes of strabismus of myopic people (strabismus myopum)—"Every one knows," he says,[32] in commencing an explanation of the mode of the origin of this strabismus, "that myopic people only use one eye when they look at near objects; while the other eye, also myopic, and its axis of vision obliquely deviating and directed towards distant objects, either sees not, or very indistinctly." This answers to the form which we have called relative diverging strabismus; it had already been described by Buffon, as occurring in his own eyes. In his own case he explains it by the difference of the images perceived by the two eyes; but, in general, he places the cause in the unusual convergence of the eyes required in myopic people. "The sight is fatigued and less distinct," he says, "than when but one eye is used." To this cause Müller gives the first place; but he mentions, in addition, that the refraction is augmented by the convergence of the eyes. However in explaining afterwards why the optic axis also permanently deviates, more or less, from the normal direction, he only refers to the disease of the one eye as a consequence of the deviation. Even then he does not say that the deviation is constantly outwards, and he based his demonstrations, in a great measure, on this erroneous opinion.

Ruete also speaks of the connexion between myopia and strabismus.[33] We have already seen, that whilst, in general, progressive myopia, of a high degree, induces relative diverging strabismus with a tendency to become absolute; yet it is only exceptionally that the convergence persists in vision at short distance; but in distant vision, it is maintained at the expense of parallelism of the lines of vision. These exceptional cases, in which the convergent strabismus, relative convergent, if one will, is complicated with progressive myopia, have been noticed by Ruete; but he did not notice the more general cases. He failed to convince himself of the presence of relative diverging strabismus, because, without doubt, he searched for it in cases of too slight a degree of myopia, where it is ordinarily wanting.

In general one is but little satisfied when one consults the more recent but

[32] L. c., S. 237.

[33] L. c., B. I., S. 226.

abundant literature of strabismus for to discover its etiology. In fact, for a long period, diverging strabismus has been completely neglected. A distinction of the various causes, according to the different forms, is not to be found, and each time that the etiology of strabismus, in general, is considered, it is evident that it is converging strabismus alone that is meant. I have yet only to allude to the writings of von Graefe, relative to the insufficiency of the internal recti, in the numerous modifications of which the gradual transition to diverging strabismus is to be sought, and, certainly, was sought for by von Graefe, and so we read in his last work:[34] "One might define insufficiency, in general terms, as a dynamic divergent strabismus, of which the degree varies, according to the distance of the objects, and which is temporarily overcome by the effort to see objects simply." We have only to recollect that this effort, in the myopic eye, becomes more and more enfeebled, for to perceive in some sort, that absolute diverging strabismus necessarily develops itself as an effort of myopia.

So our task is summed up in the following two propositions, whose antithesis is remarkable:—

1. HYPERMETROPIA DETERMINES ACCOMMODATIVE ASTHENOPIA, WHICH IS ACTIVELY OVERCOME BY CONVERGING STRABISMUS.

2. MYOPIA LEADS TO MUSCULAR ASTHENOPIA, WHICH IS PASSIVELY ELUDED BY DIVERGING STRABISMUS.

[34] Archiv. für Ophthalmologie, Bd. viii., Abth. 2.

FINIS.