after which such isomorphous crystal-structures would possess similar space-lattices, in which simply a substitution of one atom-species by another closely related one has occurred, appears to be highly probable and well justified.

b. However it cannot be denied, that under the same, or at least extremely similar circumstances of the experiment, there appear to be not only differences between the corresponding patterns in their minor details, but especially in the *number* and in the characteristic relative *distribution of the intensities* of the spots, which can only be accounted for by assuming *differences in the specific secondary radiations,* which are typical for every kind of substituting atoms especially.

It is not impossible, however, that e.g. the more or less close occupation of corresponding reticular planes in those space-lattices, will moreover play a certain rôle in the whole phenomenon.

Laboratories for Physics and for General and Inorganic Chemistry of the University.

Groningen, February 14th 1916.

Physiology. — *"On the function of the m. obliquus superior of the eye".* By Dr. C. OTTO ROELOFS. (Communicated by Prof. Dr. G. VAN RIJNBERK).

(Communicated in the meeting of January 29, 1916).

The m. obliquus superior takes its origin at the foramen opticum between the m. rectus superior and the m. rectus internus. The muscle runs medially in the top of the orbita to the front, over the m. rectus internus; near the trochlea the round tendon bends and is then directed posteriously and towards the temple. Then the tendon becomes flatter, is continued under the extremity of the m. rectus superior to attach itself in the shape of a fan to the temporal superior quadrant of the posterior bulbus-half. The line of insertion runs more or less from nasal posterior to temporal anterior.

The direction of the part of the tendon between the trochlea and the point of insertion into the surface of the bulbus is with this muscle of great importance for the mechanism of the motion. Therefore we must know the exact location of the trochlea and of the point of insertion into the bulbus. To FICK must be given credit for having first indicated, how we can determine by a system of coordinates the points of origin and insertion of the muscles of the eye. FICK and afterwards RUETE have also executed some mensurations. Later on VOLKMANN made similar mensurations much more correctly with more than 30 eyes.

VOLKMANN imagined a rectangular system of coordinates the axes of which pass through the center of rotation of the eye. The axis that connects the centers of rotation of the two eyes is called the x-axis, that is to say, positively from the center of rotation towards the temple. The axis vertically through the center of rotation is called the z-axis; whilst the part over the center of rotation is reckoned positive. The axis perpendicular to the two former, the sagittal axis, is called y-axis, the part of which behind the center of rotation was taken positive by VOLKMANN; in accordance with ZOTH and VON KRIES in the handbook of HELMHOLTZ the part of the y-axis before the center of rotation will however here be reckoned positive.

The position of the head is by no means insignificant for the mensurations of the location of the points of origin and insertion of the eye-muscles according to this system of coordinates; the head is supposed to be kept erect.

VOLKMANN admitted as point of insertion of the muscles of the eye the center of the line of insertion. If now we call the coordinates for the insertion of the m. obliquus superior x_i, y_i and z_i and for the trochlea x_o, y_o and z_o then the result of the measurements made by VOLKMANN produced the following averages:

$x_i = 2.9$ mm. $y_i = -4.41$ mm. $z_i = 11.05$ mm.
$x_o = -15.27$ mm. $y_o = 8.24$ mm. $z_o = 12.25$ mm.

For his calculations VOLKMANN admitted, that the normal eye corresponds with a globe, the radius of which amounts to 12.25 mm. whilst the point of rotation would lie 1.29 mm. behind the center of this globe, as has been determined by DONDERS and DOYER. It is necessary, that the point of rotation has a constant location not only in the eye but also in the orbita, as we determine both the place of insertion and the place of the trochlea with regard to the center of rotation. Most likely there exists neither in the orbita, nor in the bulbus oculi a real constant center of rotation. The investigations of HELMHOLTZ, DONDERS, MÜLLER, VOLKMANN, WOINOW, BERLIN and others have taught us however, that we are certainly not far from the truth, if we admit a constant point of rotation for the normal eye, so that consequently the region called by HERING the interaxial space of the bulbus, is also very small. Therefore we shall not make great errors, if we continue to make use of the data supplied by VOLKMANN in this respect.

Some objections can however be raised against the results communicated by VOLKMANN and afterwards reproduced in the literature, namely:

1. Too little attention is constantly paid to the fact that the figures supplied by VOLKMANN are only averages, and that the extremes sometimes differ considerably. These extremes are not the consequence of errors made in the mensuration or calculation, but originate in anatomical individual oscillations.

2. VOLKMANN's calculation of z_i from x_i and y_i is not exactly correct, as he has not sufficiently paid attention to the fact, that the center of rotation lies 1,29 mm. behind the central point. The formula used by him $z_i = \sqrt{r^2 - x_i^2 - y_i^2}$ ought to have been $z_i = \sqrt{r^2 - x_i^2 - (y_i - 1.29)^2}$ in which r is the radius of the globe.

3. The calculation of y_0 is very complicate and is found by the calculation of a great number of averages, so that it is very doubtful whether great signification may be attributed to a value obtained in this way, even if the mensurations are made in 30 cases.

The first objection may be met by taking likewise account of the extremes in the succeeding calculations. The second objection requires only that the calculation is made a second time. The third objection can likewise be met in a degree by introducing a simpler calculation from the data supplied by VOLKMANN himself. VOLKMANN namely has measured with 33 different eyes the angle between the y-axis and the direction of the tendon projected upon the horizontal plane going through the center of rotation. For this he found:

minimum: 40°10′, maximum: 61°3′, average: 47°24′

VOLKMANN remarks here emphatically, that the probable error of his determinations amounts to only $^1/_{100}$, and that consequently the important difference between the two extremes proves, that the location of the m. obliquus superior and the mechanical operations resulting from it, are subject to very great individual oscillations.

If now we know x_i, y_i and x_0, then it is very simple to calculate y_0 by means of the mentioned angle, which we shall call henceforth $\angle q$, according to the formula $y_0 = (x_i - x_0) \cot. q + y_i$.

With the help of the minima, maxima and averages for x_i, y_i and q we can now likewise calculate for y_0 a minimum, maximum and average. The results of the mensurations of VOLKMANN, somewhat modified on account of my considerations and calculations, are the following ones:

x_i: min. 0.5 mm., max. 5.5 mm., average 2.9 mm.
y_i: min. — 1.71 mm., max. — 6.71 mm., average — 4.41 mm.

z_i: min. 7.47 mm., max. 11.87 mm., average 10.45 mm.
x_o: with only slight oscillations. average — 15.27 mm.
y_o: min. 2.01 mm., max. 22.90 mm., average 12.30 mm. (8.24 mm.,
z_o: with only slight oscillations, average 12.25 mm.

From the location of the trochlea and of the point of insertion of the m. obliquus superior we can calculate the position of the plane in which the couple lies that is formed by contraction of this muscle. We shall call this plane the plane of motion. The axis of motion of this muscle stands in the center of rotation perpendicular to this plane of motion. The plane of motion does not entirely correspond with the muscle-plane, which is defined as the plane going through the trochlea, the point of insertion of the muscle and the central point of the eye. The plane of motion namely goes through the trochlea, the tangential-point of the muscle and the point of rotation of the eye; by the tangential point we understand the point where the muscle first touches the bulbus oculi. I should consequently be obliged first to calculate the location of the tangentialpoint; for simplicity's sake, however, I have not done so and admitted as plane of motion the plane going through the trochlea, the point of insertion of the muscle and the center of rotation of the eye, as this can occasion only an insignificant error. By means of this plane I have calculated the location of the axis.

Now we can calculate the location of the axis of motion for the averages and for all combinations of the different extremes. These calculations have been made by me for six cases; these cases we call *a*, *b*, *c*, *d*, *e* and *f*. With *a* and *b* the averages have been used, only y_o is in the two cases different.

For *c* I took $\angle q$ as large as possible, x_i as large as possible, y_i as small as possible. In this eye we may expect: a strong rotation, a feeble abduction, a feeble deorsumduction.

For *d* I took $\angle q$ as large as possible, x_i as small as possible y_i as large as possible. In this eye we may expect: a strong rotation, a strong abduction, a feeble deorsumduction.

For *e* I took $\angle q$ as small as possible, x_i as large as possible, y_i as small as possible. In this eye we may expect: a feeble rotation, a feeble abduction, a strong deorsumduction.

For *f* I took $\angle q$ as small as possible, x_i as small as possible y_i as large as possible. In this eye we may expect: a feeble rotation, a strong abduction, a strong deorsumduction.

Just like VOLKMANN I shall call the angle of the axis of motion with the x-axis $\angle \lambda$, with the y-axis $\angle \mu$ and with the z-axis $\angle \nu$.

Now the axis of motion makes with each of the coordinate-axes 2 angles, which are each other's supplements. Therefore VOLKMANN uses, in imitation of FICK, for his determinations the part of the axis of motion, located at that side of the center of rotation, seen from which the muscle turns the eye according to the hands of a clock. The angles λ, μ and ν, which I have calculated for the 6 different cases, are consequently not equal for the right and for the left eye but each other's supplements. The following table, which represents the results of my calculations, contains only the values found for the right eye.

	a	*b*	*c*	*d*	*e*	*f*
x_l	2 9 mm.	2.9 mm.	5.5 mm.	0.5 mm.	5.5 mm.	0.5 mm.
y_l	— 4.41 „	— 4.41 „	— 1.71 „	— 6.71 „	— 1.71 „	— 6.71 „
z_l	10.45 „	10.45 „	10.53 „	9.26 „	10 53 „	9.26 „
x_0	—15.27 „	—15.27 „	—15.27 „	—15.27 „	-15.27 „	—15.27 „
y_0	8.24 „	12.30 „	9.78 „	2 01 „	22.90 „	11.97 „
z_0	12.25 „	12.25 „	12.25 „	12.25 „	12.25 „	12.25 „
$\angle \lambda$	54°58′	47°17′	61°39′	60°37′	43°53′	42°24′
$\angle \mu$	36°56′	43°31′	29° 6′	44° 7′	50°52′	55°39′
$\angle \nu$	79°45′	83°14′	96° 4′	60°24′	106°3′	68°20′
moment *s*.	0 80 KR	0.73 KR	0. 87KR	0.72 KR	0.63 KR	0.56 KR
moment *t*.	0 57 „	0.68 „	0.47 „	0.49 „	0.72 „	0.74 „
moment *v*.	0.18 „	0.12 „	—0.11 „	0.49 „	—0.28 „	0.37 „

If we call the moment for the total couple KR, we can with the help of the place of the axis separate this couple into three different couples, which move the eye respectively round a sagittal, a transversal and a vertical axis, and calculate the moments of these. The moment for the sagittal axis (moment *s*) is $KR \cos \mu$, for the transversal axis (moment *t*) is $KR \cos \lambda$ and for the vertical axis (moment *v*) is $KR \cos \nu$. The result of the calculations is likewise indicated in the table above; the negative values with moment *v* indicate an adducing moment.

Consequently we see, notwithstanding important individual oscillations, that the m. obliquus superior serves in the very first place for the rotation of the eye inwardly (moment *s*) or, what means the same, to compensate rotating moments outwardly, that however for looking downward the m. obliquus superior is neither entirely insignificant, though, according to ZOTH, the moment of the m. rectus inferior is three times larger for looking downward. For the abduction, on the contrary, the m. obliquus superior has only a very slight signification, and in cooperation with other abducent forces it can, at best, support the abduction somewhat.

Does the knowledge we have obtained enable us also to estimate in some degree the maximal excursion of the eye by contraction of the m. obliquus superior? By excursion we must understand the angle that the eye makes, moving round a constant axis of motion, in this case through contraction of the m. obliquus superior.

VOLKMANN supposed that he could give an affirmative answer to this question, by admitting that the maximal excursion was reached, when the point of insertion coincided with the tangential point. He adds to this, that with further contraction of the muscle, no rotation would take place, but a removal of the center of rotation. The maximum found by him for the average eye amounted to 26° 55′.

A few objections might be raised against this conclusion:

1. Beside the couple that moves the eye, there exists always a force that tries to remove the center of rotation. As soon however as the point of insertion has reached the tangentialpoint, the force that tries to remove the center of rotation will become proportionally greater.

2. The calculated maxima of excursion of the 4 mm. recti do not correspond with the size of the field of vision.

Calculated maxima of excursion according to VOLKMANN	Size of the field of vision according to						
	VOLKMANN	SCHUURMANN	AUBERT	KÜSTER	HERING	NAGEL	
M. rect. ext. 60°43′	38°	42°	38°	43°	43°	50°	abduction
M. rect. int. 29°31′	42°	45°	44°	45°	45°	50°	abduction
M. rect. sup. 41°38′	35°	34°	30°	33°	20°	45°	upward
M. rect. inf. 41°43′	50°	57°	57°	44°	60°	45°	downward

3. The maximal excursion for the two obliqui calculated according to VOLKMANN would amount for the m. obliq. sup. to: 26° 55′, for the m. obliq. inf. to: 78° 18′. This relation is not probable.

4. If we calculate from the maximal excursion and the length of the muscle-fibres (likewise measured by VOLKMANN) the maximal abbreviation of the different muscles of the eye, then those would

oscillate between 0.15 and 0.48. This can neither be reasonably admitted.

At last some doubt might rise with regard to the signification of this maximal excursion, as after all an isolated contraction of the m. obliq. sup. does not occur in the normal eye. I am however of opinion, that the knowledge of the maximal excursion can for all that give us an impression of the signification of this muscle for the normal motion of the eye. If we take moreover into consideration that, after having reached the tangential point through the point of insertion, the muscle operates so unfavourably, that we cannot expect such an inappropiate construction in the normal movements, than VOLKMANN's calculations are by no means insignificant.

Therefore I have calculated for the average eyes a and b the excursion that is required to bring the point of insertion into the tangential point. At the same time I have added hereto two cases g and h in the following way g: x_i as large as possible, y_i as large as possible, $\angle q$ average, consequently excursion as large as possible; h: x_i as small as possible, y_i as small as possible, $\angle q$ average, consequently excursion as small as possible.

The results were:

For eye a:	$x_i = 2.9$ mm.	$y_i = -4.41$ mm.	$y_0 = 8.24$ mm.	maxim. excursion	22°27′
„ „ b:	$x_i = 2.9$ mm.	$y_i = -4.41$ mm.	$\angle q = 47°24′$	„ „	24° 8
„ „ g:	$x_i = 5.5$ mm.	$y_i = -6.71$ mm.	$\angle q = 47°24′$	„ „	46° 9′
„ „ h:	$x_i = 0.5$ mm.	$y_i = -1.71$ mm.	$\angle q = 47°24′$	„ „	6°32′

The very important oscillations render it desirable in suitable cases of paralysis of the muscles of the eye to investigate this maximal excursion more closely. In a case of oculomotorius paralysis from the clinic of Prof. WERTHEIM SALOMONSON I thought I might conclude from the field of vision, that this excursion amounted to $\pm$ 30°.

In the functions of the m. obliquus superior it is especially the position of the line of vision that requires our attention. The latter is however indicated by different authors in a widely different way, and it is therefore necessary that in the first place we agree how we shall indicate the position of the line of vision in our cases.

HELMHOLTZ has indicated, that with erect head and looking forward in the distance the line of vision assumes a position nearly coinciding with the primary position of the eye, i. e. the position from which the eye moves in all directions without rotating round the line of vision, consequently according to the law of LISTING. The axes of motion are then always lying in a frontal plane, going through the center of rotation (plane of LISTING).

We shall only then speak of *rotation* in case the eye makes a motion or assumes a position that does not correspond with the law of LISTING. The rotation is then measured by the angle through which the eye must rotate round the line of vision as axis to answer to the law of LISTING.

By *abduction* and *adduction* I shall understand the smallest angle that the line of vision makes with the sagittal plane.

By *deorsumduction* and *sursumduction* I shall understand the smallest angle that the line of vision makes with the horizontal plane.

The extent of the *rotation* will depend upon the angle between y-axis and axis of motion and of the excursion that the eye has made round the axis of motion.

We can express this in the formula $\text{tg.}\ {}^1/_2\, R = \cos\mu\ \text{tg.}\ {}^1/_2\, E$, in which $\angle R$ = rotation, $\angle \mu$ = angle between y-axis and axis of motion, $\angle E$ = excursion.

For the *abduction* holds · $\sin A = \sin E \cos\nu + (1 - \cos E)\cos\lambda\cos\mu$ or

$$\sin A = 2\sin^2 {}^1/_2\, E\,(\cot. {}^1/_2\, E\cos\nu - \cos\lambda\cos\mu)$$

For the *deorsumduction* holds: $\sin D = \sin E\cos\lambda - (1 - \cos E)\cos\mu\cos\nu$ or

$$\sin D = 2\sin^2 {}^1/_2 E(\cot. {}^1/_2\, E\cos\lambda - \cos\mu\cos\nu)$$

In these formulae A = *abduction*, D = *deorsumduction*, E = *excursion*, whilst λ, μ and ν represent the angles of the axis of motion with the x-, y- and z-axis. If the axis of motion lies in the plane of LISTING (frontal level) the formulae become much less complicate namely:

$$\sin A = \sin E\cos\nu$$
$$\sin D = \sin E\cos\lambda,$$

In this case E indicates at the same time the angle between line of vision and y-axis. If the axis of motion does not lie in the plane of LISTING, then the angle between line of vision and y-axis ($\angle H$) is expressed in the formula:

$$\cos H = \sin^2\mu\cos E + \cos^2\mu \quad \text{or}$$
$$\sin {}^1/_2\, H = \sin\mu\sin {}^1/_2\, E.$$

An isolated function of the m. obliq. sup. is inconceivable in a normal eye. Such an isolated function is only possible with definite paralysis of the muscles of the eye.

We must however call the attention to the fact, that with a paralysis of the muscles of the eye the center of rotation is likely to change its place somewhat, as the constant location of the center of motion is a function, partly of the tensions of the tissues, and the resistances of the tissues partly of the distribution of the tensions over the different muscles. It is likewise the question, whether the eye will really rotate round a constant axis, as in reality the position of the eye does not only depend upon the strength of the contracting muscle, but also upon the elasticity and resistance of the different surrounding tissues.

If we disregard these inaccuracies, the data supplied formerly will enable us to make a conception of the way that the line of vision follows during an isolated contraction of the m. obliq. sup. An inward rotation and deorsumduction will prevail; the abduction will be only insignificant, but a little more important than we expect, as the center of the cornea does not move downward along a large circle.

If we know the excursion and the location of the axis, we can calculate from these, according to the above-mentioned formulae, the rotation, the deorsumduction and the abduction.

On the other hand, if we have determined by investigation the rotation, the deorsumduction and the abduction, we can calculate from these the location of the axis in the following way.

$$\sin H = \sqrt{\sin^2 A + \sin^2 D} \qquad (H = \text{angle between line of vision and } y\text{-axis})$$

$$tg\mu = \frac{tg\,{}^1/_2 H}{tg\,{}^1/_2 R}$$

$$\cos\lambda = \frac{\sin\mu}{\sin H}\left(\sin{}^1/_2 R \sin A + \cos{}^1/_2 R \sin D\right)$$

$$\sin\nu = \frac{\sin\mu}{\sin H}\left(\cos{}^1/_2 R \sin A - \sin{}^1/_2 R \sin D\right)$$

If the m. obliq. sup. cooperates with one of the other muscles of the eye then the rotating-moments of the different axes (x, y and z-axis) can either strengthen or neutralise each other. If the m. obliq. sup. cooperates with the m. rectus inf. then the rotating moments (for y-axis) can neutralise each other; the rotation downward, the deorsumduction, is strengthened. If the m. obliquus sup. cooperates with the m. rectus sup., then the moments for rotation round the x-axis will be able to neutralise each other, so that the result is an almost accurate rotation round the y-axis (reflectory counter-rotation when the head is moved round a sagittal axis). A cooperation with the m. obliq. inf. will not easily occur, except for fixation of the eye, as the planes of motion of these muscles almost coincide. Only with abduction a not important cooperation may be expected.

I wish to discuss a little more elaborately the cooperation of the m. obliq. sup. with the m. rectus ext. or with the m. rectus int. The view is often expressed that with an abduction of such a nature, that the line of vision coincides nearly with the axis of motion of the m. obliq. sup. a contraction of this muscle would merely rotate the eye inwardly round a sagittal axis, with an adduction on the contrary of such a nature, that the line of vision lies in the plane of motion of the m. obiq. sup., a contraction of this muscle would move the eye downward without rotation. This view cannot be entirely correct. We may not first let an abducing or adducing force operate and afterwards let the m. obliq. sup. operate, as if nothing had happened to the eye. We could as well first let the m. obliq. sup. operate and then let an abducing or adducing force influence. The result, the position of the eye, would then be quite different. In the two cases the tensions of the muscles might be equal, the resultant of the tensions of the tissues unequal; it is impossible that there could be equilibrium in both cases. We come nearer to the truth, if we ask ourselves, what is the resultant of the two muscle-tensions, how is the plane of motion of this resultant located? The eye will namely assume a position, as if it had come into this new position from its primary position, through the resultant of these muscle-tensions. For simplicity's sake I let here the primary position coincide with the anatomical position of rest of the eye.

The axis of the resultant will be located in the plane going through the axes of the two components. When the m. obliq. sup. cooperates with an abducing or adducing force, the planes of motion of resultant and components will always cut each other in one line, whatever the relation of the forces may be. With abduction the y-axis is located over the plane of motion of the resultant, with adduction under it. A result of this fact is, that with cooperation of the m. obliq. sup. with an abducing force the deorsumduction is much less important, than with cooperation with an adducing force. If the abducing force $= K_h$, the adducing force $= - K_h$, the resulting force $= K_{,}$, and the location of the resulting axis determined by the angles $\lambda_{,}$ (with x-axis) $\mu_{,}$ (with y-axis) and $\nu_{,}$ (with z-axis) then the following formulae hold:

$$K_{,} = \sqrt{K^2_h + K^2_0 + 2K_hK_0 \cos v}$$

$$tg\, v_{,} = \frac{K_0 \sin v}{K_h + K_0 \cos v}$$

$$\cos \lambda_{,} = \frac{\sin v_{,} \cos \lambda}{\sin v} \qquad \cos \mu_{,} = \frac{\sin v_{,} \cos \mu}{\sin v}$$

In the normal eye, it has already been discussed, the cooperation of the muscles will always be such, that the eye assumes such a position, as if it had come into that position by rotation round an axis in the plane of LISTING. This is no more true for the extreme limits of the field of vision, and neither with convergention. The law of LISTING makes it necessary, that the resultant of the moments of rotation for the y-axis is $= 0$, or, if necessary, compensates a similar moment of rotation in consequence of the tension of the tissues. Consequently it cannot be correct, that the m. obliq. sup. operates by preference when looking down in adduction. On the contrary the signification of the m. obliq. sup. is to be found chiefly in the fact that, cooperating with the m. rectus inf., it is able, when looking down, to satisfy, as much as possible, all the requirements of the law of LISTING, and of the binocular vision, even if the resistances of the tissues are somewhat more irregular, or the relations for rendering binocular single vision possible are somewhat more difficult. The m. rectus inf. alone could never satisfy all these requirements.

Chemistry. — "*On Cathode Scattering in Electrolysis*". By Dr. A. H. W. ATEN. (Communicated by Prof. A. F. HOLLEMAN).

(Communicated in the meeting of January 29, 1916).

1. *Introduction.* In the electrolysis of aqueous solutions, deposition of metal or generation of hydrogen takes place at the cathode, for so far as the discharge of positive ions is concerned. The two processes can also take place side by side. The hydrogen formed can arise through direct discharge of the hydrogen ions present, (primarily), or also in consequence of this that metal ions present in the solution are discharged, and the metal formed through this decomposes the water (secondarily). Both in case of primary and of secondary generation of hydrogen the cathode can undergo a change, which consists in this that the surface, which is smooth at first, becomes rough, or that the metal of the cathode scatters through the liquid in very finely divided state. This latter phenomenon is indicated by the name of cathode scattering. The roughening of the cathode-surface is essentially the same as the cathode-scattering, and differs from it only in intensity.

The cathode scattering for lead, tin, and other metals was first observed by BREDIG and HABER [1]). If one of these metals e.g. lead is made cathode in a solution of potassium or sodium hydroxide, or in diluted sulphuric acid, then for a not two small current density a scattering of the lead takes place, which spreads through the liquid in black clouds. HABER [2]) and SACK [3]) explain this phenomenon,

[1]) Ber. **31** (1898) 2741.

[2]) Z. f. anorg. Chemie **16** (1898) 447, Z. f. Elektrochemie **8** (1902), 245.

[3]) Z. f. anorg. Chemie **34** (1903) 286.