Physiology. — *"Tonic reflexes of the labyrinth on the eye-muscles"*. By Prof. R. MAGNUS and A. DE KLEIJN.

(Communicated in the meeting of June 28, 1919).

It is a well-known fact, that the labyrinths strongly influence the position of the eyes in the orbits. Each position of the head namely, corresponds to a special, definite position of the eyes in the orbits.

The inquiries concerning the relation between the position of the labyrinth and that of the eye is highly impeded by spontaneous movements of the eyes and it is, therefore, easy to understand that more elaborate investigations were made almost exclusively with animals, which make but few such spontaneous movements. Among the animals, which are usually experimented on, the rabbit is preferred to all others.

In 1917 an extensive publication on this subject was issued by the pharmacological Institute [1]), in which the question of the relation between the positions of the labyrinth and of the eye was examined as completely as could be. Starting from a primary position of the head with a horizontal mouth-opening and the lower jaw pressed downward, other positions of the head appeared to involve both *constant vertical deviations of the eye* and *rotatory movements;* as for *side-movements,* in the direction of the eye-opening, no reliable data could be found.

The vertical deviations of the eyes always take place in opposite directions for the two eyes, whereas the principal deviations were found with the head in the two side-positions, when the upper eye deviated as much as possible downwards, the lower eye in the same degree upwards.

The rotatory movements always take place in the same direction for both eyes, the greatest deviations were found, when the head stood with its muzzle vertically upwards or downwards. During the experiments the rabbits were put immovably in various positions with regard to their surroundings, when special care was taken that any shifting of the position of the head with regard to the trunk was out of

[1]) J. v. d. HOEVE und A. DE KLEIJN. Tonische Labyrinthreflexe auf die Augen. Pflügers Archiv. 169. 241. 1917.

the question (reflexes of the neck). The various positions of the eyes were determined kinematographically. Minute measuring was made possible by indicating on the photographic plates the shifting of a cross, burned into the cornea anaesthetized by cocain, with regard to a fixed system of coordinates, photographed at the same time. The results were indicated for the vertical deviations of the eye and for the rotatory movements separately, to wit for three perpendicular rotations of the head round 360° each.

In this way we only get to know, of course, the influence of the head, i. e. the labyrinths on the position of the *eyes*. However, for a minute analysis of the influences of the labyrinths it is desirable to know the influence of the labyrinths on each *eye-muscle*.

Now, as different positions of the head often bring about a combination of vertical deviations of the eye and rotation movements, which combination, in its turn, variously modifies the points of insertion of the eye-muscles, it stands to reason that we cannot say beforehand that the greatest deviation of the eye-ball either upwards or downwards, or the full extent of any of its rotations, necessarily implies the maximum lengthening or shortening of the eye-muscles (recti and obliqui). This made it necessary to investigate what position of the head produced the maximum and minimum shortening of the eye-muscles. The above-mentioned inquiry had clearly brought out in what way each position of the head influences the position of the eyes, so that the only thing left to be done now, was construction of a proper model of an eye, putting the eye-ball of this model in the various positions which had been found, and measuring the length of the six eye-muscles for each position accurately.

A short time ago the anatomical relations of the eye-muscles of rabbits were given in detail by WESSELY [1]). However the accompanying illustrations do not give us the numbers expressing those relations.

For this reason a minute inquiry was made with various rabbits with regard to the length of the eye-muscles, size of the eye-ball, place of insertion for each muscle, etc. and in accordance with this the instrument-maker of the Institute, Mr. F. A. C. IMHOF, made a model of an eye-ball with eye muscles to correspond.

Starting from the primary position of the eyes and guided by the information obtained before with regard to rotatory movements and vertical deviations of the eye for different positions of the head, now

[1]) K WESSELY. Ueber den Einflus der Augenbewegungen auf den Augendruck. Arch f. Augenheilkunde. 81. 111. 1916.

the eyes of the model were placed in the corresponding position, so that now the lengths of the 6 eye-muscles for these various positions of the eyes could be measured.

In the experiments made before, three rotations had always been performed. Rotation I.

The animal originally in ventral-position with horizontal mouth-opening, Rotation of the animal round the bitemporal axis, direction of the rotation head downwards and tail upwards.

Rotation II.

The animal originally in ventral position, with horizontal mouth-opening. Rotation of the animal round the occipital-caudal axis. Direction of the rotation: Right eye downwards.

Rotation III.

The animal originally in side position, left side downward, right eye upward, vertical mouth-opening. Rotation of the animal round the venter-dorsal axis. Direction of the rotation: muzzle downwards.

For each rotation the position of the eyes was stated accurately after every 15°.

The result of the measurements of the lengths of the eye-muscles of the model for the various positions of the eyes was stated in tabular form.

However, the publication of these tabular statements must be put off for the moment, as some correction appeared to be necessary.

For when the eye, starting from the normal position, performs *rotations, unaccompanied by vertical movements,* these rotations of the eye-ball cause the points of insertion of the rectal eye-muscles on the bulb to be removed, by which the length of the rectal eye-muscles is changed passively.

However, when a rotatory movement combines with a vertical deviation of the eye, the contraction of the rectal eye-muscles does not take place with the length of those muscles of the normal position of the eye, but with the length they have got by (after) the rotation (contractions of the oblique eye-muscles). So when the eye has performed rotation the lengths of the eye-muscles must be rectified with a value, in accordance with the passive lengthening or shortening, caused by the contraction of the oblique eye-muscles.

At the same time, of course, the lengths of the m.m. oblique at different vertical deviations should be rectified with a value, in accordance with the passive lengthening or shorting of those muscles caused by the contraction of the rectal eye-muscles.

With the help of the model it was easy enough now, by first putting the eye in the normal position and stimulating either rotatory movements or vertical deviations of the eye-ball exclusively, to

state for various lengths of the oblique eye-muscles, the passive lengthening or shortening of the rectal eye-muscles, or conversely, for various lengths of the rectal eye-muscles the passive lengthening or shortening of the oblique eye-muscles.

The tabular statements, corrected according to this system, have been reproduced as curves on fig. 1—4.

So these curves represent the rectified lengths in m.m. of the 4 eye-muscles (both oblique and recti super. and infer.) for the three rotations of the head above-mentioned. For the obliq. superior only the distance from trochlea to the insertion on the bulbus has been reproduced. From all this we learn that curves of the obliq. superior and obliq. inferior form a true reflexion of each other, that is to say that, at the tonic reflex of the labyrinth these muscles act as antagonists, the lengthening of the one brings about the shortening of the other, and conversely.

At the same time the curves of the m.m. recti superior and inferior show that these muscles too are absolute antagonists.

If we compare the curves of the oblique eye muscles (fig. 1 and 2) with the curves, found at a former period for the rotatory movements of the eye, we see, that they agree with regard to the principal points. Especially the positions of the maxima and minima do not show any essential difference; the rotatory movements and the shortening of the oblique eye muscles are greatest when the head with its muzzle points vertically upward or downward. At the same time the curves for the rectal eye-muscles (fig. 3 and 4) agree with the curves, found before for the vertical deviations of the eye. Only the shape of the curve of the eye-muscles at rotation III is a little bit more pointed than the shape of the curve, found for the vertical deviations.

However the position of the maxima and minima undergo no essential change. The maximum contraction of the two rectal eye-muscles takes place when the head is almost in side position.

Now, comparing the curves of the obliqui and recti, we find the following:

At rotation I (—) the obliqui react strongly whereas the recti hardly perform any movement.

So, at this rotation we find no vertical deviations, but almost all of them are rotatory-movements.

On the other hand, at rotation II (—.—.) the obliqui hardly react at all, whereas the recti superior and inferior perform strong movements; so for this rotation the vertical movements prevail, whereas rotatory movements do not take place.

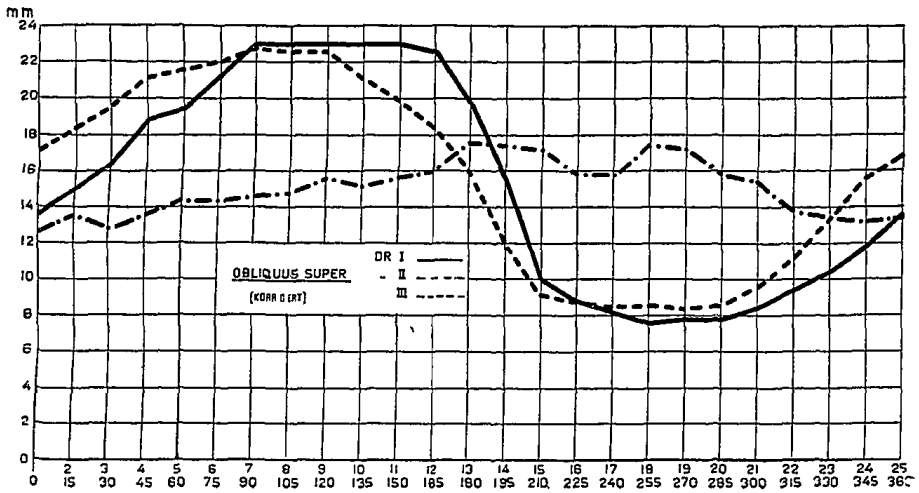

Fig. 1.

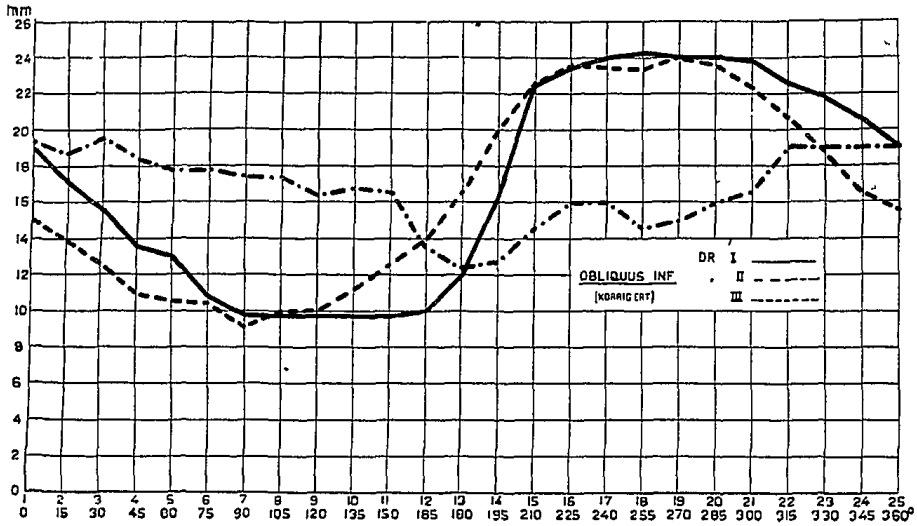

Fig. 2.

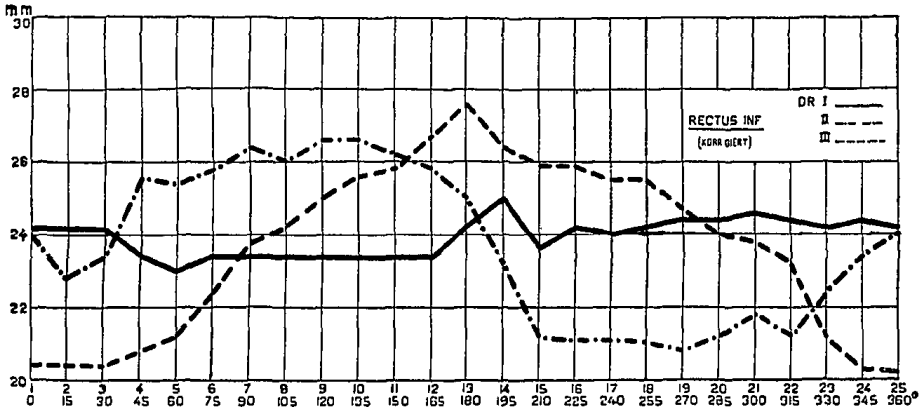

Fig. 3.

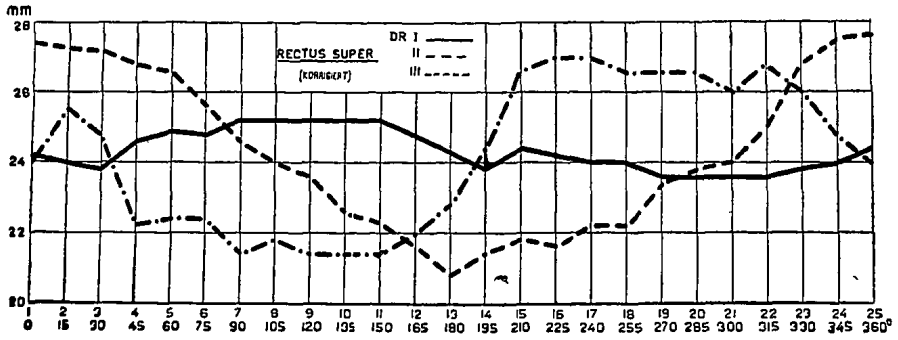

Fig. 4.

Only for rotation III (—.—.—.) we find a combined reaction of the obliqui and the two recti.

From this we may safely conclude that, at rotation I the labyrinths influence almost exclusively the obliqui, at rotation II almost exclusively the rectus superior and inferior and at rotation III all four eye-muscles.

We cannot yet enter into details about the curves, but will do so afterwards, when determining how far the tonic reflexes of the labyrinth on the eye depend on definite parts of the labyrinth special of the otolithes. Be it sufficient to indicate here that for the oblique eye-muscles the curve of rotation I shows an asymmetric course, whereas for the rectal eye-strings the same thing takes place at rotation II.

The exactitude of the former definitions and the measurements now performed, may be derived from the comparison of the corresponding points on the different curves.

For the three different rotations namely, it occurred several times that the same potition of the head was reached from different directions. The curve shows that, notwithstanding this, the lengths found for the eye-muscles agree wonderfully.

Corresponding points are among others:

Normal position. Rotation I No. 1 and 25. Rotation II No. 1 and 25.

Back position. Rotation I No. 13. Rotation II No. 13.

Side position (Left). Rotation II No. 19. Rotation III No. 1.

Side position (Right). Rotation II No. 7. Rotation III No. 13.

Muzzle upwards. Rotation I No. 19. Rotation III No. 19.

Muzzle downwards. Rotation I No. 7. Rotation III No. 7.

For all these positions the four eye-muscles measured have almost exactly the same length.

Conclusions.

From this and the inquiry published before we may conclude

the following with regard to the tonic reflexes of the labyrinths on the eye-muscles:

1. With the rabbit every position of the head corresponds with a special state of contraction of the eye-muscles and therefore with a special position of the eyes, which lasts throughout the time that the head retains the same position.

2. With the rabbit for the rectus externus and internus no reliable data could be found in the bringing about of these tonic reflexes of the labyrinth. It is especially the rectus superior and inferior which cause the vertical deviations of the eye and the two obliqui which cause the rotation movements.

When this happens, the two recti, just like the two obliqui, act as antagonists, on the other hand, changes of the lengths of the recti may combine with those of the obliqui in various degrees. So these two groups of muscles act independently of each other (though of course dependent together on the labyrinths).

3. When the head stands with its muzzle vertically upwards, the two obliqui superiores (right and left) are in a state of greatest contraction, the two obliqui inferiores in a state of greatest relaxation.

The upper cornea-poles of both eyes are then rolled forward. When the head stands with its muzzle in a position vertically downwards, the two obliqui superiores are in a position of greatest relaxation, the two obliq. inferiores in a position of greatest contraction. The upper cornea-poles of both eyes are rolled backward.

For all other positions of the head we find contractions, lying between these two extremes, the two eyes always react with rollings in the same direction.

4. When the head is in side-position (left) the right rect. inf. and the left rect. superior are in a state of greatest contraction, the right rectus superior and the left rectus inferior in a state of greatest relaxation. Then the right eye has its maximum deviation downward, the left eye its maximum deviation upward. When the head is in side position (right), the left rect. inf. and the right rect. sup. are in a state of greatest contraction, the left rectus superior and the right rect. inf. in a state of greatest relaxation. For all the other positions of the head we find states of contraction of the rectus superior and inferior lying between these two extremes. Both eyes always react with opposed vertical deviations of the eye. The rectus superior of one side and the rectus inferior of the other side react in the same sense.

5. When we start from the normal head-position and we turn

it round the bitemporal axis (360°), it is principally the obliqui which react, whereas the two eyes roll in the same direction. Starting from the normal position and turning the head round the occipital-caudal axis (360°), it is especially the recti superior and inferior which react, and the eyes show opposed vertical deviations.

Starting from the side-position and turning the head round its venter-dorsal position (360°), both groups of strings react and the eye-positions are the combined results of opposed vertical deviations and rotatory movements equally directed.

6. After extirpation of the labyrinth on one side the vertical deviations of the eye and the rotatory movements continue for *both* eyes. *One* labyrinth influences the obliqui of both eyes and the rollings in the same sense; however the recti (sup. and inf.) of the two eyes and the vertical deviations of the eyes are influenced in the opposed sense.

For both eyes *one* labyrinth brings about the greatest vertical deviation of the eye with respect to its normal positions when it is lowest down, whereas the head is in side-position. Then the rectus super. of the same side and the rectus inf. of the crossed side are in a state of greatest contraction.

One labyrinth brings about, for both eyes, the greatest rotatory movements by contraction of the obliq. infer., when the head stands with its muzzle vertically downward.

On the other hand the greatest rotatory movements of both eyes by contraction of the obliqui superior are brought about by *one* labyrinth, when the head stands with its muzzle vertically upwards.

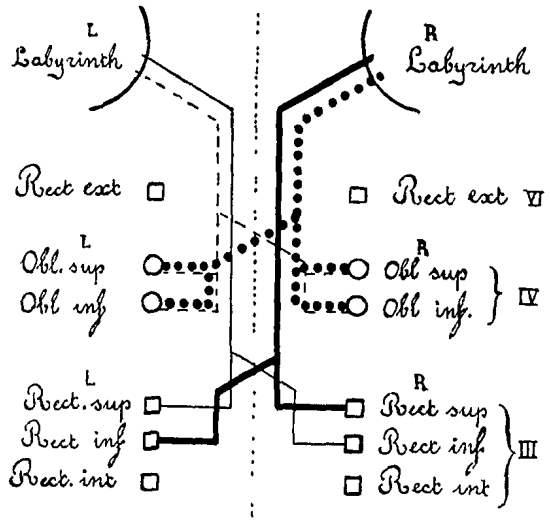

Fig. 5.

With *one* labyrinth the size of these rotatory movements is about half of that of animals with intact labyrinths.

7. For the intact animal it is possible to calculate the changes in the eye-positions by taking the sum of the influences, starting from the right and left labyrinths, on the recti super. and infer. and the obliqui super. and inf. of the two eyes.

8. After extirpation of the labyrinths on *both* sides all tonic reflexes on the eyes, mentioned above, disappear.

9. The *minimum* number of central courses, necessary for the explanation of the *tonic* reflexes of the labyrinths of the rabbit on its eyes (so *not* of the rotations-reactions and caloric reactions), have been drawn in a sketch, accompanying fig. 5.

The uninterrupted lines represent the courses of the recti super. and inf., the dotted lines those of the obliqui.

Each of the four obliqui is influenced from both labyrinths, each of the two recti (super. and infer,) from only *one* labyrinth.

One labyrinth influences the 4 obliqui, but only the rect. super. of the same side and the rect. inf. of the crossed side. For these *tonic* reflexes of the labyrinth for the m.m. externus and internus no reliable data could be found.