**Physiology.** *"A further Contribution concerning the function of the Otolithic Apparatus."* By Prof. R. MAGNUS and A. DE KLEYN.

(Communicated at the meeting of May 27, 1922).

In a previous publication [1]) we demonstrated that when caviae are centrifuged by WITTMAACK's method, being thereby deprived of otolithic membranes, the labyrinth-reflexes *resulting from position* (tonic labyrinth-reflexes on the extremities, "Labyrinth stell-reflexes", and compensatory eye-positions) will disappear, but that, on the other hand, the labyrinth-reflexes *responding to movement* (rotatory actions and after-reactions on head and eyes and the reflexes on progression-movements) will persist. It follows that the above position labyrinth-reflexes are otolithic reflexes, since change of position of the head in space does not enable us to elicit a *change* of the stimulation in the sensory epithelium of the otolithic maculae, but does not at all mean that the sensory epithelium cannot, under these circumstances, be in a permanent condition of stimulation. It is *a priori* quite possible that the sensory epithelium of the maculae, like that of the retina, continually produces stimuli, whose magnitude, in the absence of the removed otolithic membranes, can no more be altered by the changes of position of the head in space.

This conception was brought home to us by experiments to be published afterwards.

In order to go further into this subject we started from the following consideration:

The extirpation of *one* labyrinth in a normal animal brings about an intricate complex of phenomena. A previous minute inquiry [2]) into these phenomena enabled us to establish the following symptoms as resulting directly from the unilateral extirpation of the otoliths (membranes + sensory epithelium) or rather from the activity of the otolithic organs on one side only:

*a.* Rotation and flexion of the head towards the missing labyrinth.

*b.* Eye-deviation: the eye on the side of the removed labyrinth, deviating downwards, the other upwards..

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[1]) These Proceedings, Vol. XXIII, p. 907.

[2]) Pflügers Archiv. 154. 178. (1913).

As secondary results from the rotation of the head sub *a* appear change of posture of the whole body, difference of tonus in the extremities, rolling movements etc.

We do not know as yet which part of the labyrinth is responsible for a transitory difference of tonus in the extremities, which persists also with the head in the normal position towards the trunk. This symptom has, therefore, to be left out of consideration in the following discussion.

On the basis of these findings we performed the following experiments:

Caviae were centrifuged after the familiar method of WITTMAACK. Now only those animals were used for further experimentation in which clinically all labyrinth-reflexes of position disappeared and all movement-reflexes maintained themselves, or, in other words, animals in which it could be expected that all the otoliths had been completely detached on either side.

In order to eliminate as much as possible a stimulating, or paralysing influence of the removal itself on the sensory epithelium, the animals were regularly examined and the experiment proper was started only from 7 to 9 days after the centrifugation.

In this procedure about 0.1 cc. of a 5% cocain solution was injected unilaterally through the ear-drum into the middle-ear, in order to paralyse the whole labyrinth on that side.

If it should now appear that, after the removal of the otoliths, the sensory epithelium of the maculae was not in a condition of stimulation, it could be expected that no phenomena should reveal themselves after the cocain injection, with the exception only of a nystagmus consequent on the elimination of the *semicircular canals* on the injected side.

If, however, there is indeed, after the removal of the otoliths a stimulation in the sensory epithelium of the maculae, we may look for asymmetrical phenomena after the cocain-injection, since at the injected side the sensory epithelium is completely paralysed and there is a constant condition of stimulation at the other side.

After the cocain-injection a rotation of the head towards the injected side ("Grunddrehung"; utriculus) and an eye-deviation (eye at the injected side down, the other eye upwards; sacculus.) may then be expected, i. e. phenomena agreeing with those appearing in *normal* animals, if ipsilaterally the labyrinth is paralysed through extirpation or through injection. With this difference, however, that the phenomena in animals with removed otoliths do not vary, as is the case in normal animals after unilateral extirpation of the

labyrinth, with the various positions of the head in space consequent on the varying influence of the otoliths of the unimpaired side, but that these phenomena are constantly the same whatever the position of the head of the animal under examination may be, when it is held up freely in the air.

Five similar experiments were made, which are instanced in the following three protocols:

*Cavia R:*

28/6 1921: All labyrinth-reflexes normal.
Centrifugation: head up, chest inward, time 2 minutes, rate 1000 m. per minute.

2/7 1921: Total lack of tonic reflexes.

4/7 1921: Reflexes of the semi-circular canal: rotation-reactions towards the right positive, to the left weak.
Progression-reactions: doubtful or lacking.
Total lack of tonic reflexes.

5/7 1921: Reflexes of the semi-circular canal (also progression-reactions) all present and symmetrical.
Tonic reflexes: all present. Sits symmetrically, no eye-deviations. In dorsal position with head in normal position to the trunk: no distinct difference of tonus in the extremities.

$11^h$ 39′. 0.1 cc of 5% cocain solution into *left* middle-ear.

$11^h$ 41′. Held up in the air with head down: head 90° towards the right. When sitting O D [1]) down O S [2]) up (consequently stimulation of the left labyrinth).

$11^h$ 43′. Head down: head symmetrical again.

$11^h$ 47′. Head down: head 20—30° rotation to the left, slightly turned to the left. When sitting a slight levoversion of the head, no distinct eye-deviations.

$11^h$ 49′. Head down, 45° levo-rotation. When sitting falls on the left side. Head in normal position: no distinct difference of tonus in the extremities. If moved on the ground to the right much greater resistance then against moving to the left, strong inclination to the left (incipient paralysis of the left labyrinth).

$11^h$ 51′. Head down: 70° levo-rotation. When sitting head-nystagmus towards the right. Is moved on the ground: rolling to the left. No distinct eye-deviation.

$11^h$ 54′. Head down 90° levo-rotation. O S slightly downwards. O D upwards.

$12^h$. O S weak nystagmus beats anteriorly upwards. O D posteriorly downwards. No change of the phenomena with a change of the position of the head in space.

$12^h$ 3′. Marked spontaneous nystagmus, direction as at $12^h$.

$12^h$ 6′. Marked deviation and nystagmus, do not change with a different position of the head in space.

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[1]) O D means Right eyeball.

[2]) O S means Left eyeball.

6/7 1921: Reflexes of the semicircular canal: all present and symmetrical.
Tonic reflexes: all absent, asymmetry of cocain-test quite disappeared.
12h. Decerebration, fair stiffness.
Shifting from ventral to dorsal position: no trace of tonic labyrinth-reflexes. Rotation of the head in lateral position: Typical cervical reflexes, no labyrinth-reflexes.

*Cavia S.*

28/6 1921: All labyrinth reflexes present and normal.
Centrifugation: head up, chest inward, time 2 minutes, rate 1000 m. per minute.

4/7 1921: Reflexes of semicircular canal: asymmetric reflexes. Rotation-reactions on head and eyes with rotation to the right weak, with rotation to the left strong.
Progression-reactions: weak; extension of the legs even lacking.
Tonic reflexes: lacking, only slight „Grunddrehung" to the left.

7/7 1921: Reflexes of semicircular canal: present and symmetrical. Progession-reactions weak but present.
Tonic reflexes: lacking, no more „Grunddehung". Sits symmetrically. No eye-deviation.
Dorsal position head in normal position towards the trunk; no difference of tonus in the extremities.
Injection of cocain in the *left* middle-ear.
12h 30′. Held up in the air, head down: dextro-rotation of head (stimulation of the left labyrinth).
12h30½′. Head down: head, in normal position, not turned.
12h31′. Head down: levo-rotation of the head (incipient paralysis of left labyrinth).
12h31½ Head down: 60° levo-rotation of the head.
12h33′. When sitting, head turned and flexed to the left: clock-hand movements to the left, no nystagmus.
12h 34′. O S downward, O D upward; no nystagmus.
12h 34½′. Marked eye-deviation, no nystagmus: no difference of deviation with change of position of head in space. Head down: head turned 90° to the left.
12h 36′. Right lateral position: head in position of normal sitting animal.
Left lateral position: head in dorsal position.
Dorsal position: head right lateral pos.
Head up: head left lateral position.
} No change of the rotation of the head with different position of the head in space.
12h 38′. No nystagmus.
12h 40′. Rotation to the right and to the left: eye-rotation reaction and nystagmus.
„ „ „ „ „ „ : head rotation reaction spositive.
On the ground: clock-hand-movements to the left; pushed with experimentator's foot: rolling once to the left.
12h 52′. Evident eye-deviation: for the first time very strong spontaneous nystagmus, O S anteriorly upward, O D posteriorly downward.

4h. When sitting, head flexed and with maximum rotation to the left, marked rolling movements, strong spontaneous nystagmus.

8/7 1921: Tonic reflex entirely lacking. Yesterday's asymmetry quite disappeared.

9/7 1921: Animal dyspnoeic. Decerebrate rigidity not good.
Tonic labyrinth reflexes decidedly not present.

*Cavia F.*

28/5 1921: All labyrinth-reflexes positive.
Centrifuged with head up, chest inward, time 2 minutes, rate 1000 m. per minute.

31/5 1921: Semicircular canal reflexes: Rotation-reactions and after-reactions: positive.
Progression-reactions: lift-reaction positive, the others weak.
Tonic reflexes: lacking.

2/6 1921: Reflexes of semicircular canal: all positive. Tonic reflexes: lacking.

5h 12'. 0,05 cc. 10% cocain through left tympanum.

6 hour. Sitting with head placed in the normal position: O D upward, O S downward (incipient paralysis of left labyrinth).

6h 2'. Sitting with head turned a little towards the left, the whole animal inclines to the left.
Hanging with head down: "Grunddrehung" 90° to the left.

6h 6'. Rotating with head *inward*, rotating to the left, weak rotation-reaction of the head, distinct after-reaction. Dextro-rotation: marked rotation-reaction of the head and no after-reaction.

6h 7'. Eye-rotation reactions: dextro rotation, distinct reaction with nystagmus, no after-reaction. With levo-rotation: reaction and afterreaction.

6h 10'. Progression-reaction: Liftreaction not distinct.
"Springing reflex" positive.
Muscular tremor: positive in all directions except posteriorly.
Tonic labyrinth-reflexes negative.
Position of the head in the air with:
Right lateral position: head in normal position to the trunk through "Grunddrehung", often hangs down.
Left lateral position: head in dorsal position through "Grunddrehung".
Head up: head in left lateral position, animal now becomes restless (cocain-action).
Head down: head turns 90° to the left.
Dorsal position: head in right lateral position through levorotation, often also in dorsal position with left flexion.
} Ergo constant rotation of the head, which does not change with change of position of the head in space.

6h 18'. When sitting with head placed in the normal position: OD anteriorly upward, O S posteriorly downward. Nystagmus just the opposite way.

6h 33'. Right lateral position: O S posteriorly downward, nystagmus the opposite way. Eye-deviation and nystagmus of the left eye are the same with right and left lateral position of the head and equally strong; the same holds good also for O D.

7/6 1921: Animal sits symmetrically, no eye-deviation.
Reactions of semicircular canal: all positive.
Tonic reflexes: all lacking. Asymmetrical phenomena quite gone as in cocain-test.

8/6 1921: Like previous day. When sitting, head sometimes turned very slightly to the right, for the rest animal sits symmetrycally, no eye-deviations.

*Anatomical examination by* Dr. M. DE BURLET. *All otolithic membranes detached.*

Right sacculus; sensory epithelium without membrane; the otolithic membrane isolated in the sacculus between ductus endolymphaticus and the back-part of the sensory epithelium.

Right utriculus; sensory epithelium without membrane; the otolithic membrane lies between the posterior portion of the macula and the entrance to the crus commune.

Left sacculus; sensory epithelium without membrane: the otolithic membrane rests against the lateral wall of the sacculus and above the macula.

Left utriculus: sensory epithelium without membrane; the otolithic membrane is detached towards the inner side and above the macula but lies in the utriculus.

These experiments go to show that for more than a week after the removal of the otolithic membranes the sensory epithelium is still in a constant condition of stimulation. When one labyrinth is for some time eliminated by cocain, the stimuli emanating from the non-injected labyrinth will induce asymmetrical phenomena, similar to those after unilateral extirpation of the labyrinth in normal animals, with this difference, however, that in the centrifuged animals injected unilaterally with cocain, these phenomena do not change with a *change* of position of the head in the air.

Considering that there was a week's wait after the centrifugation, it is probable that the above condition of stimulation should no longer be ascribed to centrifugation, and that, therefore, to the sensory epithelium of the maculae the power should be assigned of eliciting stimuli, which, owing to the absence of the otolithic membrane, do not vary much as to strength.

The function of the otolithic membranes, then, consists in altering the intensity of this condition of stimulation of the sensory epithelium. This stimulation will be stronger or weaker according as the membranes pull at the epithelium or press upon it.

Relative to the portion of the sacculus (the main part) innervated by the N. saccularis it has been previously demonstrated that the stimulation decreases with pressure and increases with pulling. This mechanism exists probably also for the utriculusmaculae.

It appears that for the division of the sacculus (sacculus corner) innervated by the N. utricularis the relations are more intricate.

Our results may perhaps be conducive to the proper conception of the function of the sensory epithelium of the otolithic maculae.

The above-named property of the otolithic apparatus to elicit continuous stimuli even after the otolithic membranes are detached — as here described — undoubledly demands attention in the further study of the unilateral affection of these organs.

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