nuclei I always saw one nucleolus and in less-developed ones often there were two. Probably also in Eunotia the nucleoli which appear in the daughter-nuclei gradually coalesce.

The primary division-wall, of which mention has been made, is a lamella easily soluble in dilute chromic acid. The siliceous shells are formed later. I have not found a centrosome in Eunotia.

Conclusions.

In Eunotia major Rabenh. the nucleus divides karyokinetically just as in other Diatomaceae, a fact established by LAUTERBORN and KARSTEN. In Eunotia major a central spindle (Zentralspindel) also occurs, a body which plays an important part in karyokinesis, as the above authors have also shown in other Diatomaceae. Well-developed chromosomes are not found in Eunotia major. The nuclear network forms short bodies of indefinite shape, which crowd round -the central spindle and form an annular nuclear plate, which divides into two annular halves; these separate from each other along the central spindle and develop into daughter-cells.

With regard to the chromosomes, I may say that my results agree with those of KLEBAHN and KARSTEN, but not with those of LAUTERBORN. He found in Surirella calcarata and other Diatomaceae, in the mother-nucleus as well as in the daughter-nuclei, well developed long chromosomes, whose number could be ascertained (16 or more). KLEBAHN has not been able to see such chromosomes in Rhopalodia gibba nor KARSTEN in Surirella saxonica, but as I did in Eunotia major they found only a few short thick bodies of various shapes which could not be accurately described, and whose number was indeterminate. It must be remembered that the results which differ were obtained with different species.

Physiology. — *"On a shortening-reflex"*. By Prof. J. K. A. WERTHEIM SALOMONSON.

(Communicated in the meeting of December 28, 1912).

By the expression shortening reflex I propose to indicate the contraction of a muscle, the ends of which are passively brought nearer together. I shall try to prove this contraction to be a real reflex; though the primary shortening of the muscle may not be the direct cause.

We shall first consider what happens when any part of an extre-

mity is moved passively, in which case one set of muscles is stretched, another group being shortened.

A living animal's muscles at rest are generally not entirely relaxed. A slight degree of elastic tension, called *tonus*, persists. Tonus is for the greater part caused and restrained by regulating impulses, originating from peripheral sensory and higher motor neurones. Also the cortex and the gangliongroups of the cerebrum, the labyrinth, the cerebellum control and influence the muscular tonus. Tonus varies under different circumstances, but it adapts itself automatically to the rate of stretching of the muscle. If the muscle be slowly stretched by a passive movement of the limb, its form changes. The muscle grows longer and thinner. But its tension does not change at the same rate. Only if the stretching be carried very far or happens within a very short space of time its elastic tension grows appreciably.

With a passive shortening of the muscle something analogous occurs The length diminishes, the diameter increases but the tension adapts itself automatically to the new condition, and the muscle does not become slackened so far as to show folds or furrows.

This adaptibility only persists as long as the muscle remains in contact with the intact nervous system. As soon as the muscle is freed from its nerve, its reflex-tonus disappears and it seems to behave simply as an elastic string, in which a definite tension corresponds to a definite length. The action of the nervous system seems to equalise the tension for different lengths and causes the resting-length of an innervated muscle to be a varying quantity.

If the passive shortening of a muscle is effected within a very short time *we sometimes observe a genuine contraction of the muscle* followed by the thickening caused by the reflextonus. This phenomenon I have called the shortening reflex.

If the foot be passively and somewhat forcibly extended (= dorsal flexion) we are sometimes able to see and feel a very short contraction of the m. tibialis anticus. After this contraction the tonus-thickening becomes visible. The contraction cannot be elicited in every healthy individual, and even where it is to be found, it is often rather difficult to obtain. We get it most easily in the tibialis anticus by extending the foot. In some cases I have also found it in other muscles, as in the flexors of the arm, the flexors of the leg after flexing the arm or the leg.

I have recorded the phenomenon with a special apparatus, constructed some 9 years ago for recording the foot-clonus. The difficulty was to rigidly attach a pair of MAREY's tambours to the bony parts of the leg, so as not to become displaced by the violent movements

of the leg during the clonus. This difficulty was overcome by attaching a clamp to the upper part of the tibia and another to both malleoli, and connecting them by a very light hollow rod. To this rod the tambours were screwed with a pair of collars. With this arrangement which proved to be entirely satisfactory, I was able to record the thickening curve of any desired muscle of the leg and also the displacement of the foot with respect to the leg.

Fig. 1.
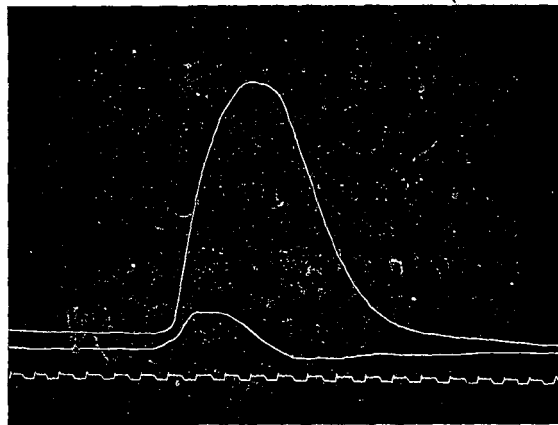
Shortening reflex in the tibialis anticus of a healthy
man.
Upper curve: displacement of the foot.
Middle curve: thickening curve of tibialis anticus.
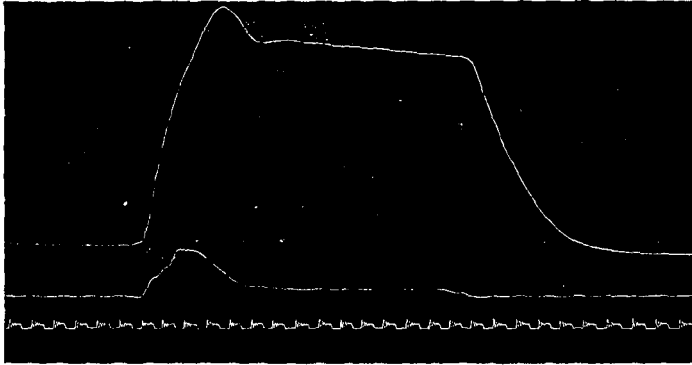Lower curve: time marks of 0.1 second.

I reproduce a few records (fig. 1 and fig. 2) which were taken in this way. The upper line shows the movement of the foot; rising of the curve indicates dorsal flexion. The middle curve is a record of the thickening of the tibialis anticus. The time curve gives marks of 0,1 of a second.

Fig. 1 shows the tibialis contraction occurring with a short dorsal flexion of the foot. Fig. 2 gives the record of tibialis contraction caused by a rapid dorsal flexion of the foot, the foot being kept in dorsal flexion for nearly two seconds. In this last record we clearly see the initial tibialis twitch-followed by the reflextonus-thickening.

From the records we soon gather the fact, that the tibialis response immediately follows the foot movement. By comparing a great many records we also find that the interval between the commencement of the foot-movement and the beginning of the tibialis-muscle-twitch is of a very short and yet extremely constant duration. If as

the beginning of the footmovement be taken a point where the curve has risen about 1 millimetre, and a similar point on the

Fig. 2.

Shortening reflex in the tibialis anticus of a healthy
man.
Upper curve: displacement of the foot.
Middle curve: thickening curve of tibialis anticus.
Lower curve: time marks of 0.1 second.

tibialiscurve as the commencement of the muscle-twitch, the interval comes out as something between 0.028—0.032 second.

This fact points in the direction of a reflexphenomenon. If we had to deal with a voluntary contraction, the latent period would have been a great deal less constant. It is also a fact, that the interval between an external stimulus and the commencement of a voluntary movement is of the order of 0.12—0.15 second with a fairly experienced subject. Constancy of this latent period is only to be expected with the most experienced subjects or after a special training. The latency of sensory reflexes is much more constant, but it depends in most cases chiefly on the intensity of the stimulus. The highest constancy is shown only in the deep reflexes, in which the intensity of the stimulus does not seem to possess any influence on the latency. The latent period of the superficial reflexes is generally of the order of 0.07—0.09 of a second, whereas the deep reflexes show a latency of the order of 0.035 second. With these figures we have to take into account that the latency is measured from the commencement of the stimulus until the commencement of the muscular response as indicated by the *mechanical* record. If we had recorded the current of action we should have found lower figures.

In my experiments I was not able to get more exact or smaller

figures for the latency. This was not due to the fact that I used a mechanically recording instrument, but only to the difficulty in determining the exact moment of the stimulus. The stimulus is applied during the passive movement of the foot. But we cannot tell the exact moment at which the stimulus is produced. Must the foot move with a certain velocity or must it travel over a certain distance? Perhaps both conditions are necessary. At least with a very slow movement of the foot we only obtain the tonus-thickening and with a very rapid movement over a short distance only, we sometimes fail and sometimes succeed in getting it. Therefore it is impossible to indicate the exact point in the record of the foot-movement which is to be considered as the beginning of the stimulus. If I take the first point in which both curves begin to rise from the zero-line, I find a latency from 0.038—0.045 of a second, with an average of 0.041 second. If we take a rise of 1 millimetre in both curves as the beginning of the stimulus and the response, we get an average of 0.029 second. Though the exact figure is doubtful, it is yet of interest to note that it agrees closely with the average latency found in the deep reflexes.

The duration of the muscular response has also to be considered. From direct observation and also from most of the records we come to the conclusion that we have before us a simple muscle-twitch, the duration of which is something between 0.2—0.5 second. Only in cases where the foot has been moved with great force, or has been kept in prolonged dorsal flexion, a muscular response of longer duration may be found. But in these cases the contraction shows a peculiarity, clearly visible in fig. 3, viz. a second contraction appearing before the first is finished. We shall consider this point later on.

As from our observations we see that : 1$^{\text{ly}}$ the latent period is constant, 2$^{\text{dly}}$ that the latency agrees with the latency observed in deep reflex, 3$^{\text{dly}}$ that the contraction is generally a simple muscle-twitch, we may conclude that the phenomenon itself is a real reflex.

This being established we may ask where the reflexcentrum is situated, which is the reflexogene mechanism and which is the significance of the reflex.

We may conclude from the latency that the reflexcentrum cannot be situated very high up in the central nervous system. I believe that another supposition as a medullary seat for the centrum need not be considered. The reflex has a close similarity to the deep reflexes and may probably be regarded as a third group of this kind; the other groups being formed by the tendonreflexes and the periost-reflexes.

It is somewhat more difficult to understand the reflex-mechanism. We only know that the reflex is elicited by passive dorsal flexion of the foot. But then two things happen simultaneously : the extension-muscles of the foot are shortened and the triceps surae is stretched. Which of the two causes the reflex ? I fail to see the possibility of choosing between the two on clinical grounds only. In the accident of a torn or cut Achillestendon, which is unlikely to occur in a healthy man, only a positive result would have any significance, as the reflex cannot invariably be elicited in healthy individuals. Some pathological arguments might perhaps be brought forward in support of the hypothesis, that the reflex is primarely caused not by the shortening of the muscle itself, but by the stretching of the antagonist.

As regards the significance of the reflex we may assume that it is the same as that of more elementary reflexes, viz, a means of protecting the organism against exogene stimuli. The obvious fact is that the contraction assists the automatic tonus-mechanism in attaining as soon as possible the necessary muscular tension corresponding to the changed attitude. Hence we conclude that the reflex is a protecting mechanism against a total want of control over the position of the foot, if the foot is passively moved.

I have already mentioned that in a few records a second contraction of the tibialis anticus appeared immediately after the first (fig. 3). This may be caused either by a voluntary or by an invo-
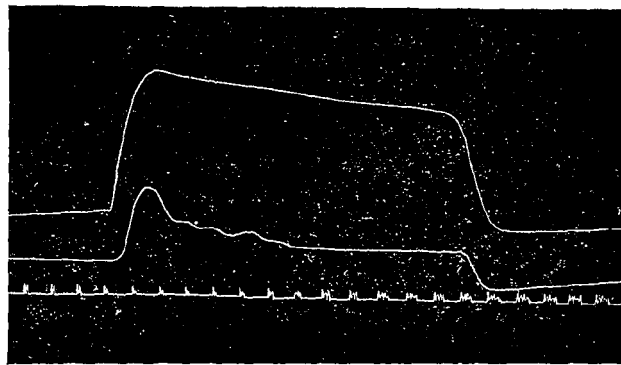
Fig. 3.
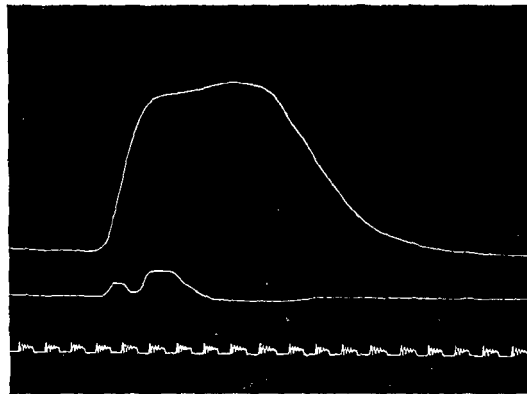
Shortening reflex of the healthy leg of a hemiplegic
patient.

luntary impulse. In my experiments I have tried to exclude as much as possible any voluntary movements by impressing upon the subjects

to keep their muscles relaxed, and to try not to make any movement. Judging from the curves, this request has been attended to, as the duration and form of the second contraction seem to exclude the possibility of a voluntary origin. I think I may assume that the second contraction was not caused by any intended or conscious impulse. But then we have two possibilities. Either the second contraction was also a reflex-response, but from a higher nervous level, or it might be the first from a strongly damped clonus. I am inclined to think, that in most cases the second contraction was caused by a reflex from a higher level, though I cannot prove it. But on the other hand I must also accept the other explanation. Amongst a series of curves taken from the "normal" leg of a hemiplegic patient, which often show the form of fig. 3, I found one single record

Fig. 4.

Curve from the same patient from whom fig. 3 was taken.

reproduced in fig. 4. Here we see that the tibialis contraction as soon as it is started, degenerates into a series of rhythmic, gradually ceasing clonic oscillations. In another patient suffering from a medullary disease, I obtained the record, shown in fig. 5. This record differs from the fig. 1—4 in as much as the upper curve does not represent the movement of the foot, but the thickening of the triceps surae. We immediately see, that the dorsal flexion of the foot starts the reflex and at the same time a series of clonic contractions in both the tibialis anticus and the triceps surae. These last contractions prove at least the possibility of the second tibialis contraction being the first of a strongly damped clonus.

As yet I have not considered the literature. There is some reason for this, as I have not been able to find in it any reference to a

reflex such as has been described as appearing in healthy subjects. I have only found the well-known paradoxical contraction of

Fig. 5.
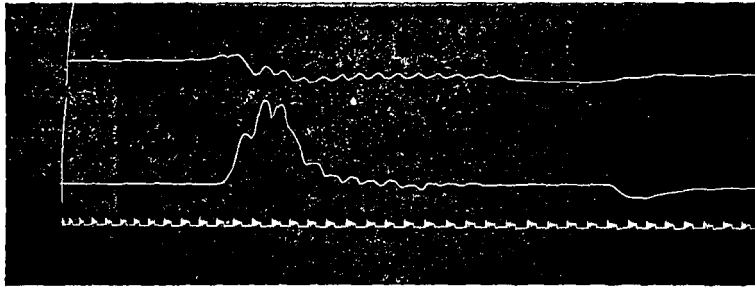
Shortening reflex in a case of arteriosclerotic medullary disease; clonic contractions in triceps (upper curve) and tibialis anticus (middle-curve).

WESTPAHL (1880), which is a *tonic* contraction of the tibialis anticus appearing at dorsal flexion of the foot in some patients. It is of rather long duration, WESTPAHL observing a contraction of 27 minutes, ERLENMEIJER of 45 minutes' duration. CHARCOT has seen the same contraction, also after massage of the calves and has taken graphic records, one of which, taken from his article in BRAIN (VIII p. 268) I reproduce here (fig. 6). From this curve and the explanatory text, also reproduced, we immediately see, that this contraction is not at all the same thing as the shortening reflex. .

But there seems to be no doubt, that a relationship exists between

Fig. 6.
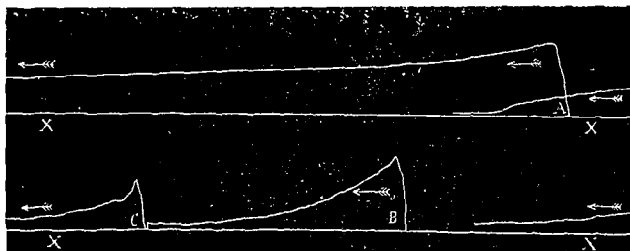
Same patient (April 12th). Tracing of contraction of the tibialis anticus obtained by massage of the muscles of the calf. — A, B, C, beginnings of three consecutive experiments. (In this and the last figure—much reduced in size—the length of XX represents one whole turn of the cylinder, viz. thirty minutes.)

the shortening reflex and the paradoxal contraction. I am inclined to suppose that the latter is the pathological form of the first.

The curves I have given as physiological were those taken in a patient with a severe trigeminus-neuralgia caused by periostitis alveolaris, who is now cured. His reflexes were not altered in the least.

The curves 3 and 4 were taken from the healthy side of a hemiplegic patient and are perhaps not to be considered as purely physiological. There is some reason to suppose, that hemiplegia may cause a heightening of the shortening reflex of the healthy extremity.

Amongst the pathological forms of the reflex we might perhaps include some forms of hysterical contracture and also some cases of crampi. But I intended to consider only the physiological aspects of the reflex.

Physics. — *"On the thermodynamical functions for mixtures of reacting components."* By Dr. L. S. ORNSTEIN. (Communicated by Prof. H. A. LORENTZ).

(Communicated in the meeting of November 30, 1912).

In his dissertation Dr. P. J. H. HOENEN has developed a theory of the thermodynamical functions for mixtures of reacting components [1]. Considerations closely connected to those of this dissertation are obtained if the statistical method of GIBBS is applied to the study of the equilibrium in chemical systems. I will show this in the following communication, and will restrict myself to the case that only one kind of reactions is possible in the mixture, the extension to other cases being possible without any difficulty.

In the following considerations I shall use a canonical ensemble of the modulus $\Theta \left(=\dfrac{R}{N} T \right)$ (R is the constant of Avogrado for the grammolecule, N the number of molecules present in this quantity of matter. We might as well use the micro-canonical ensembles, but for the calculations then being somewhat more complicated.

The molecules participating in the reaction are indicated by $\mu_1 \cdot \cdot \mu_x \cdots \mu_k$ Then the reaction will be characterised by the stoechiometrical formula

$$\sum_{1}^{k} \nu_x \mu_x = 0 \qquad \qquad (1)$$

the numbers ν_x indicating the smallest numbers of molecules that

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[1] Dissertation Leiden 1912, comp. also these proceedings XV p. 614.