anæsthetic cornea, but they appear to arise in places where the superficial corneal epithelium has been denuded.

In a case recorded by Richardson,⁴ one week after the operation a slight haziness of the cornea was observed, but as this is stated to have been present before the operation, we cannot regard it as of much significance.

In Krause's case⁵ two months after the operation the cornea remained perfectly clear, although there was complete anæsthesia both of the cornea and conjunctiva.

Doyen⁶ one year after ablation of the Gasserian ganglion found the cornea quite anæsthetic and without any evidence of trophic disturbance.

It is, therefore, seen that, with the exception of the accidental panophthalmitis in one of Rose's cases, no progressive destructive change occurred in the cornea after operation for ablation of the Gasserian ganglion. It should be borne in mind that in none of these cases has the actual position of the lesion been definitely determined by *post-mortem* examination.

It may be stated in conclusion, therefore, that the so-called neuromyolytic phenomena associated with lesion of the trigeminal nerve are evidence of irritation of the nerve, and not of paralysis. This statement holds good, whether the lesion is situated so as to implicate the ophthalmic branch, the nerve trunk, or the intramedullary root.

ON THE INFLUENCE OF THE USE OF SUGAR ON MUSCULAR WORK.⁷

By PROFESSOR B. T. STOKVIS, M.D., LL.D.,
Amsterdam.

THE influence of sugar on muscular work is so very important, from a physiological, a dietetic, an economical, and a social point of view, that I was anxious to repeat in the Pathological Laboratory of Amsterdam the well-known experiments of Professor U. Mosso and Dr. V. Harley. I invited my pupil, Dr. Langemeyer, to examine this question in view of his inaugural dissertation, and the results he arrived at by a long-continued and skilful examination, I now take the liberty to communicate to this Section.

Professor Angelo Mosso's ergograph is so well known that it seems quite superfluous to give a description of this ingenious instrument, by means of which the total amount of work done by the muscles of the middle finger in lifting a fixed weight till fatigue set in can be measured exactly, and the time during which the muscular work is done can be determined most easily. It is also known that if the separate experiments with the ergograph are repeated too frequently, exhaustion may follow to such an extent that the whole ergographic work is reduced to a minimum, and no further work can be done. Now, Professor U. Mosso and Dr. Pavletti found that in this period sugar taken in not too great quantities and not too concentrated was able to lessen the fatigue, so that a further rather considerable amount of muscular work could be done. On the other hand, Dr. Vaughan Harley stated that a great quantity of sugar taken in addition to the ordinary food increases the amount of muscular work in a most evident manner. The result of the publication of these researches was that the question is now often considered as decided, and that already in popular papers and journals the wages and food of workmen are treated as if the beneficial effect of the use of sugar on muscular work were a well-established scientific fact. Now Dr. Langemeyer's experiments prove that this beneficial effect does not exist, or, if it exists at all, can in no way be demonstrated by the ergograph. In his first series of experiments, which are to be considered as preliminary, ergographic work was done twice a day by Dr. Langemeyer and the assistant of the Pathological Laboratory, Dr. Lechensen, with the left and the right hand, over a period of eight weeks, in order to find out the physiological variations occurring during a regular mode of life, in respect to different hours of the day, to different individuals, to different

days, etc. We shall have afterwards to return to the results of this series of experiments.

In the second series of experiments, different kinds of sugar—sweet-tasting and not sweet-tasting sugars (cane sugar, grape sugar, milk sugar), and sweet-tasting substances not belonging to the carbo-hydrate group, for example, saccharin and dulcin—were taken before doing ergographic work, in order to ascertain if the beneficial effect of sugar should be considered as the effect of a palatable condiment and due to the excitation of the nervous system produced thereby, or as the effect of a muscular food.

The result of these experiments was, in reference to the researches of Dr. Harley, which we believed quite exact up to that time, a most unexpected one. In none of the experiments was there any evidence of a beneficial effect of the use of sugar or sweet-tasting substances on the ergographic work. I have here in view the general conclusion of this series of experiments that lasted over forty days, not the conclusion which could be drawn from one single experiment, for it happened often that the amount of ergographic work was greater after taking sugar, or milk sugar or saccharin, but as often the amount of work was diminished, and in many experiments the right hand was the only one which had gained, whereas the left had lost. Yet, the total amount of ergographic work done in this series showed a real and marked increase, in reference to the total amount of work of the first series, but as this increase was a gradual one, independent of the substances that were taken, it was most natural to consider it as a simple effect of training. And so indeed it proved, for when for a control the experiments were pursued daily during more than a fortnight, in exactly the same way, but without taking any sugar or palatable sweet condiment at all, the amount of muscular work still showed the same gradual increase, so it became obvious that the normal course of training is in no way influenced by the use of sugar.

The third series of experiments was perhaps the most interesting of all. In accordance with the experiments of Professor Ugolino Mosso and his pupils the effect of the use of sugar on almost exhausted muscles was examined in this series. It is not so easy as it seems to provoke exhaustion of the muscles engaged in ergographic work by often repeated single experiments. Even if the successive experiments done with the same hand follow each other with full speed, say after six minutes, and the weight to be lifted is a heavy one—that is, 6 to 7 kilogrammes (ordinary work is done with 3 kilogrammes)—the amount of muscular work done by trained persons still represents, after two or three hours of working, one-fourth or one-fifth of the work done in the beginning. These experiments lasted from five to six weeks, and were made by four different individuals. One of them, a tall well-grown lad of 16 years, who did not understand in the least what the experiments meant, was the only one who exhibited in the beginning of the experiments all the peculiarities of real exhaustion. After sixteen or seventeen single experiments he could not do more ergographic work. Of all, he was the most fit subject for demonstrating the beneficial effect of sugar on the exhausted muscle. Yet in his case, as in all the others, the alleged beneficial effect failed completely, at least in the first weeks, for in later weeks, training still being continued, it happened from time to time that this boy, as well as another untrained young man, after exhaustion seemed to have set in, exhibited most unexpectedly a great gain of muscular work. Once there was a gain of 3 kilogramme metres without anything being eaten, another time there was a gain of 2 kilogramme metres after the use of sugar; and, finally, an extraordinary gain of 18 kilogramme metres was found after a draught of fresh water. Without being able to decide the question whether these variations are to be considered as a mere accident or as a consequence of training, it is obvious that reliable results could not be obtained by experiments of that kind in untrained individuals. And in regard to the trained ones who took part in these experiments, I can only repeat that no effect whatsoever of the use of sugar was seen on their exhausted muscles.

In the second and third series of Dr. Langemeyer's experiments the doses of sugar were moderate ones. In his fourth and last series large doses were taken in order to examine their influence on the non-exhausted muscle, as in the experi-

⁴ *Bost. Med. and Chi. Journ.*, 1894, li, p. 429.

⁵ *Deut. med. Woch.*, 1893, p. 341.

⁶ *Flandre Méd.*, No. 3, 1894.

⁷ Read in the Section of Physiology at the Annual Meeting of the British Medical Association, held in London, July-August, 1895.

ments of Dr. Vaughan Harley. As the physiological variations between different days had proved greater than the variations between morning and afternoon of the same day, Dr. Langemeyer compared the ergographical work done in the morning with that performed in the afternoon, after having taken with his luncheon at 12 o'clock 100 or 200 grammes of sugar in addition to his ordinary meal. The experiments with 200 grammes of sugar lasted seventeen days, the experiments with 100 grammes eleven days, and I lay now before you a table of the amount of work done without, and after the use of sugar.

Table showing the Amount of Muscular Work done after the Use of 100 Grammes of Sugar.

Date.	Morning: No Sugar.		Afternoon: 100 Grammes of Sugar.	
	Time during Weight Lifted.	Total Work.	Time during Weight Lifted.	Total Work.
	Seconds.	Kilogramme Metres.	Seconds.	Kilogramme Metres.
March 26	212	14 416	206	11.832
" 27	192	10 812	216	11.168
" 28	202	11 512	184	9.952
" 29	200	11 824	190	9.420
" 30	208	14.708	238	10 004
April 1	228	11.400	240	12.448
" 2	236	14 808	284	13.624
" 3	230	14.484	246	10.616
" 4	194	13 192	284	13.476
" 5	244	11.360	246	13 104
" 6	230	12.760	284	14.644
" 8	276	15.418	242	12.104
" 9	214	15.572	204	12.024
" 10	248	11.160	242	13.984
" 11	243	13.224	242	13.308
" 12	248	15.592	214	15.564
" 13	196	12.176	272	17.132
Average	226	13 200	235	12 612

Table showing the Amount of Muscular Work after taking 200 grammes of Sugar.

Date.	Morning: No Sugar.		Afternoon: 200 Grammes of Sugar.	
	Time during Weight Lifted.	Total Work.	Time during Weight Lifted.	Total Work.
	Seconds.	Kilogramme Metres.	Seconds.	Kilogramme Metres.
April 16	252	14.796	234	12.584
" 17	256	13 712	288	11.076
" 18	246	12 300	280	12 672
" 19	260	13 952	238	11.816
" 20	294	14 284	3 4	14.980
" 22	252	13 832	276	11.160
" 23	210	12 168	284	10.872
" 24	264	12 696	274	14 800
" 25	220	11.672	318	13 386
" 26	276	16.188	262	10.324
" 27	314	10 860	258	13.688
Average	261	13.322	266	12.483

As is easily seen, there is in these experiments no question of a marked influence of the use of sugar on muscular work. The difference between the work done in the morning and that done in the afternoon, after the use of sugar, is so very slight that it is of no value at all; and it is very remarkable that, notwithstanding the use of almost 4 kilogrammes of sugar, the amount of ergographic work as a whole in this series is even inferior to that obtained in the beginning of the experiments in the period of a strong training.

As a final experiment, the amount of daily ergographic work, taken every hour from 9.30 till 5.30, was noted, a separate tracing with each hand being taken, on days on which 250 grammes of sugar were taken in four equal portions, at 9, at 11, at 1, and at 3 o'clock, in addition to the ordinary diet, all other conditions remaining the same. On comparing the total amount of work on the sugar days with that obtained on the non-sugar days, the sugar days, give as the total time during which the weight was lifted, 1 hour and 48 minutes, with a

work of 302 kilogramme-metres; the non-sugar days, 2 hours and 8 minutes, with a work of 354.028, that is a difference of 20 minutes and 52 kilogramme metres in favour of the non-sugar days. It is interesting to note that these differences in favour of the non-sugar days are not to be considered as an average result, but that each separate day and each separate hand shows these differences in the same sense, as is easily seen in the following table:

Table showing the Amount of Ergographic Work done by the Right Hand on Days whereon Sugar (250 grammes) was taken, and on Days without Sugar.

Date.	250 grammes Sugar.		Date.	No Sugar.	
	Time during Weight Lifted.	Total Work.		Time during Weight Lifted.	Total Work.
	Seconds.	Kilogr. Metres.		Seconds.	Kilogr. Metres.
April 29 ...	1,046	44.996	April 30 ...	1,223	59.732
May 1 ...	1,146	52 618	May 2 ...	1,162	56.188
May 3 ...	1,130	49.872	May 4 ...	1,098	52.720
Total ...	—	147.486	Total ...	—	168.640

Table showing the Amount of Ergographic Work done by the Left Hand on Days whereon Sugar (250 grammes) was taken, and on Days without Sugar.

Date.	250 grammes Sugar.		Date.	No Sugar.	
	Time during Weight Lifted.	Total Work.		Time during Weight Lifted.	Total Work.
	Seconds.	Kilogr. Metres.		Seconds.	Kilogr. Metres.
April 29 ...	1,216	42.104	April 30 ...	1,808	62.784
May 1 ...	1,306	57.516	May 2 ...	1,334	59.716
May 3 ...	1,250	55.008	May 4 ...	1,350	62.888
Total ...	—	154.628	Total ...	—	185.388

The divergence between Dr. Langemeyer's results and those of his predecessors is as striking as possible. How is it to be explained? I venture to state that it can be fairly explained, by regarding the different factors which may influence the amount of ergographic work. In Langemeyer's researches everything was done to avoid, as completely as possible, all psychical influences by placing a low screen between the operator and the registering apparatus, so that the height to which the weight was lifted could not be seen by him. In the second place, Langemeyer succeeded, after a long time of preliminary work, in ensuring an equal method of working during the whole series of experiments. To this end, it is first necessary to fasten the arm in the instrument as tightly as possible, so that no other movement than that of the middle finger can be registered; but secondly, it is still more important that in each separate experiment there should be a perfect equality in regard to the time in which each contraction and relaxation of the finger takes place; and thirdly, in regard to the way in which the finger is moved. In regard to the time, it is obvious that the setting in movement and the relaxation of the finger, even in an interval of two seconds, can take place rapidly or rather slowly. In the first case, the interval between each single muscle contraction must be greater than in the second. Now in respect of fatigue—and all ergographic work is work till fatigue sets in—it is of course retarded by contracting the finger rapidly and letting it fall immediately after contraction, whereas moderately slow contractions and relaxations tend to induce fatigue more quickly. Therefore after the first weeks of preliminary experiments it was arranged that the contraction and the relaxation should take place, as a rule, as slowly as possible at intervals of two seconds.

It was most necessary to do so, because some persons very soon get accustomed to rapid contraction and relaxation, and thus become able to perform ergographic work six to ten times in excess to the usual work, without inducing more than the ordinary exhaustion.

Former experimenters have also drawn their attention to this point, for Professor A. Mosso spoke of it in his first communication, but is it not most remarkable that in none of the papers on the use of sugar and its influence on muscular work, this important factor is not alluded to? It is just the same with the influence of training, which, too, is never mentioned.

In regard to the third point, viz., the way in which the finger is moved, and the weight is lifted, Dr. Langemeyer found that ergographic work can be done in three ways, either by the contraction of the flexor profundus, or by the contraction of the flexor sublimis, or by contraction of the two muscles at the same time. Contraction of the flexor profundus alone produces flexion of the finger, contraction of the sublimis alone elevation, without flexion, as is easily demonstrated by mechanical pulling of the tendons of these muscles in the cadaver.

In the living subject ergographic work is usually done, and should be done, by the co-operation of these two muscles, yet a separate voluntary contraction of each of the two muscles can be easily obtained by training, in such a way that in performing ergographic work, one muscle can take the place of the other, and contraction of one is immediately followed by contraction of the other.

In this way the setting in of fatigue is again considerably retarded, and ergographic work can be performed to an amount which may many times surpass the usual work done by the simultaneous contraction of the two muscles. Ergographic work includes, therefore, many sources of error, and although I dare not say that Dr. Langemeyer's predecessors paid no heed to them, yet I am fairly persuaded that the different ways in which ergographic work can be done explain to a great extent the divergence between his results and those of former experimenters.

There is yet another point to be observed. In his preliminary experiments Dr. Langemeyer had at his disposal a great number of observations, which enabled him to be acquainted with the daily variations of the work performed under normal conditions of life. These daily variations proved, especially in the beginning of the experiments, before a real and thorough training was obtained, as great, and greater than the variations, which Dr. Harley considers as a gain caused by the use of sugar. In Dr. Harley's experiments the gain in time during which the weight was lifted, was in thirty separate tracings 519 seconds, that is, an average for one separate tracing of 17.3 seconds. Dr. Langemeyer found for himself and for Dr. Lechensen normal variations running up to 25 seconds. The gain in work was in forty separate tracings by Dr. Harley 41,938 kilogramme metres, an average of 1.3 for one separate tracing. Dr. Langemeyer found a normal variation in the beginning of his experiments of $1\frac{1}{2}$ kilogramme metres and more.

To conclude, I do not hesitate to say that till now there has not been given any experimental proof of the beneficial effect of sugar on muscular work. This conclusion is not an unexpected one. Physiology teaches us that muscle is not only a most admirable living engine, in which chemical energy is transformed into mechanical work, as was so well explained last winter by my honoured friend and colleague, Professor Engelmann, of Utrecht, in his Croonian Lecture, but that it is at the same time a great storehouse of chemical substances, able to develop chemical energy. The assimilation of these chemical substances and their storage by the muscle, go on so very slowly that an immediate influence of the ingestion of food on the amount of work done by the engine is not to be expected. Manca's experiments, and the experience of daily life, teach us that even a long total abstinence from food is not able to diminish the amount of muscular power to any appreciable extent; for in muscle we have to deal with an exceedingly well provided storehouse, and with an engine working at so little expense that 80 milligrammes of sugar (glucose) are sufficient to produce an ergographic result of more than 100 kilogramme metres. In healthy persons fatigue and exhaustion, therefore, are never

caused by want of food, but solely and exclusively by want of rest; and although it cannot be contended that the chemical energy produced by the combustion of sugar is one of the chief sources of muscular work, yet there is no plausible reason why, in order to promote muscular work, sugars should be added to the daily food. All other carbo-hydrates will do as well for the provision of the muscular storehouse with the necessary stock of chemical energy.

SUGAR AS A FOOD FOR MUSCULAR TISSUE.¹

By PROFESSOR UGOLINO MOSSO, M.D.,
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I AM pleased at being able to be present at the communication just made by Professor Stokvis, and take this occasion to congratulate him on the stimulus he has provoked to the study of ergographic work. There is in Professor Stokvis's work a new departure which is very interesting—namely, with regard to the different muscles which can act on the middle finger. He has thus opened a fresh chapter in the study of ergographic work. I have made many experiments with this instrument during the past twelve years, and have therefore had much practice, and I am sure that one must not rely on a few experiments alone, to oppose the experiments of others. This is not the place however to examine the *pros* and *cons* of this question; we have not even the time. But I cannot help pointing out that Dr. Stokvis has admitted that he has, when working with sugar, only obtained positive results when the subject had been trained by a series of experiments, and that he had obtained no results when the subject was at the commencement of his experiments.

This is the essential point of the whole question: a muscle not yet trained can be fatigued when there still remains a considerable amount of potential energy—then sugar has not an evident effect; but if the subject is well trained to the work, when fatigued, sugar absorbed from the alimentary tract soon becomes converted into dynamic energy, and gives to muscle the force it has just lost.

I think that Dr. Stokvis's work is not complete. In a criticism of results it is necessary not only to state that one's own experiments are in opposition to the results of others, but also to find out and show the reason, for these differences. The question of the nutrition and contraction of muscle is a most complicated one. Dr. Stokvis has said nothing as to the part the nervous system plays, and this is one of the principal factors in muscular contraction. I believe that here we may find one, if not the chief, cause of these differences.

In my first work on the influence of sugar on the work of muscle, Dr. Paoletti and myself² established that sugar and other carbo-hydrates increase the capacity for work of muscle. We have there pointed out:

1. The minimum dose of sugar which can exert an action on muscular work.
2. The limiting quantities necessary to give a certain effect.
3. The quantity of water best suited to be given with a certain weight of sugar.
4. The most convenient method of its administration.
5. The influence of age and of fatigue.

SUGAR AS A FOOD.¹

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CARBO-HYDRATES are known to be essential to animal life, while the experiments of Wisliscenus and Fick, as well as Pettenkofer and Voit, have shown that muscular work owes its origin to a great extent to a breaking up of the carbo-hydrates in the animal body and not to the nitrogenous con-

¹ Read in the Section of Physiology at the Annual Meeting of the British Medical Association, held in London, July-August, 1895.

² Prof. Ugolino Mosso e Luigi Paoletti, "Influenza dello Zucchero sul Lavoro del Muscolo," *Tras. della R. Accademia dei Lincei*. Roma, 1893.