

On being tired.

Contributors

Brunton, T. Lauder 1844-1916.
Brunton, T. Lauder 1844-1916
Rolleston, Humphry Davy, Sir, 1862-1944
Royal College of Physicians of London

Publication/Creation

Place of publication not identified : The Practitioner, 1909.

Persistent URL

<https://wellcomecollection.org/works/rbhp7bfh>

Provider

Royal College of Physicians

License and attribution

This material has been provided by This material has been provided by Royal College of Physicians, London. The original may be consulted at Royal College of Physicians, London. where the originals may be consulted. Conditions of use: it is possible this item is protected by copyright and/or related rights. You are free to use this item in any way that is permitted by the copyright and related rights legislation that applies to your use. For other uses you need to obtain permission from the rights-holder(s).

**wellcome
collection**

Wellcome Collection
183 Euston Road
London NW1 2BE UK
T +44 (0)20 7611 8722
E library@wellcomecollection.org
<https://wellcomecollection.org>

613.73

(107)

SL

613.73

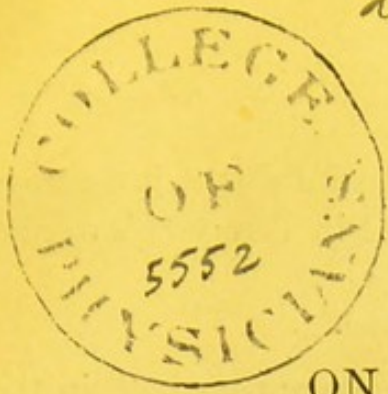




Digitized by the Internet Archive
in 2015

ROYAL COLLEGE OF PHYSICIANS
LIBRARY

CLASS	613.73
ACCN.	48741
SOURCE	
DATE	



D. H. D. Collection

with hundreds from the author
Nov. 28. 1912

ON BEING TIRED.

By SIR LAUDER BRUNTON, Bart., M.D., D.Sc., LL.D., F.R.C.P.,
F.R.S.

(Reprinted by special permission from *The Practitioner* for October, 1909.)

I HAVE chosen as the title of my paper "On Being Tired" rather than "On Fatigue," because the word "fatigue" carries with it the idea that some previous exertion has produced it, while many people are tired without any exertion whatever. For brevity's sake, however, in the course of this paper I may possibly use the terms "being tired," "fatigue," or "weariness" as interchangeable.

One constantly hears the complaint from patients that they are "always tired," and indeed some people avoid working on the ground that they are "constitutionally tired." Other people term them simply lazy, but it is quite possible that, in many of these cases, there is some physical condition in the persons which renders exertion specially distasteful to them, although other people cannot observe it. I remember perfectly well an eminent medical professor, who was acknowledged to possess brilliant abilities, but was accused by his friends of being lazy. It was only when he died, at a comparatively early age, from heart disease, which had been present for a number of years, that some of his friends, who had previously blamed him, were willing to admit that there might have been some excuse for his laziness. Like hunger and thirst, tiredness is a systemic sensation, although, just as hunger has its local seat in the stomach, and thirst in the mouth and throat, fatigue has it more especially in the eyes and muscles. Hunger, thirst, and fatigue are amongst the overpowering sensations of the body, and fatigue may be so great as to overpower the other two, and to prevent the sufferer from obtaining the food and drink which would have

25
RW 26

relieved him. Excessive weariness is so painful that it destroys the desire for life. This is well expressed in Tennyson's words :

I am a'weary, a'weary,*
I would that I were dead.

The external manifestations of weariness appear both in the face and general attitude. More especially do the signs of



FIG. 1.—To show Effect of Fatigue on the Eye. A, Vigorous and alert.
B, Wearied.

weariness appear in the eyes, which lose their lustre. The eyes seem to sink into the head, and the eyelids droop so as to lessen the palpebral opening (fig. 1). The muscles of the face become relaxed so that the lower jaw tends to drop, and, although it may not do so to such an extent as to open the

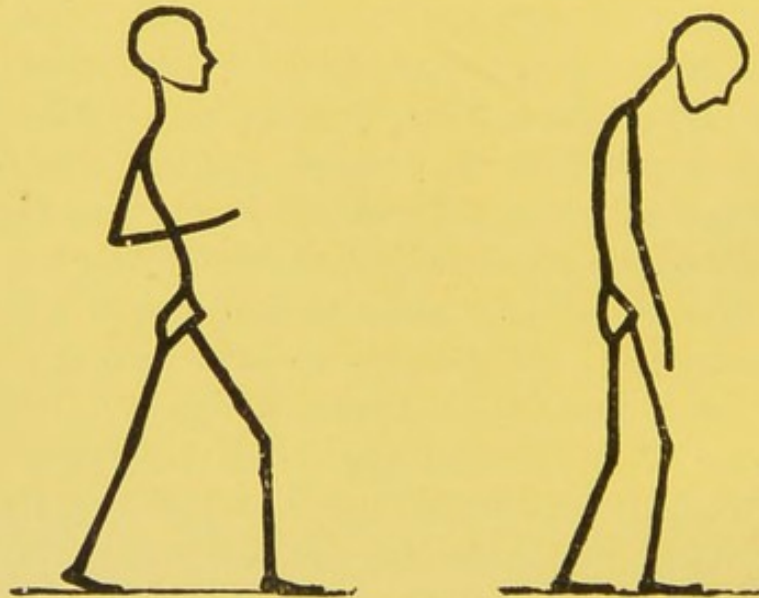


FIG. 2.—Energy and Fatigue.

mouth, it yet gives the face a drawn look. The other muscles of the body also become relaxed, so that the head tends to droop, the back to bend, the arms to fall helplessly down, and the knees to bend under the weight of the body (fig. 2). The

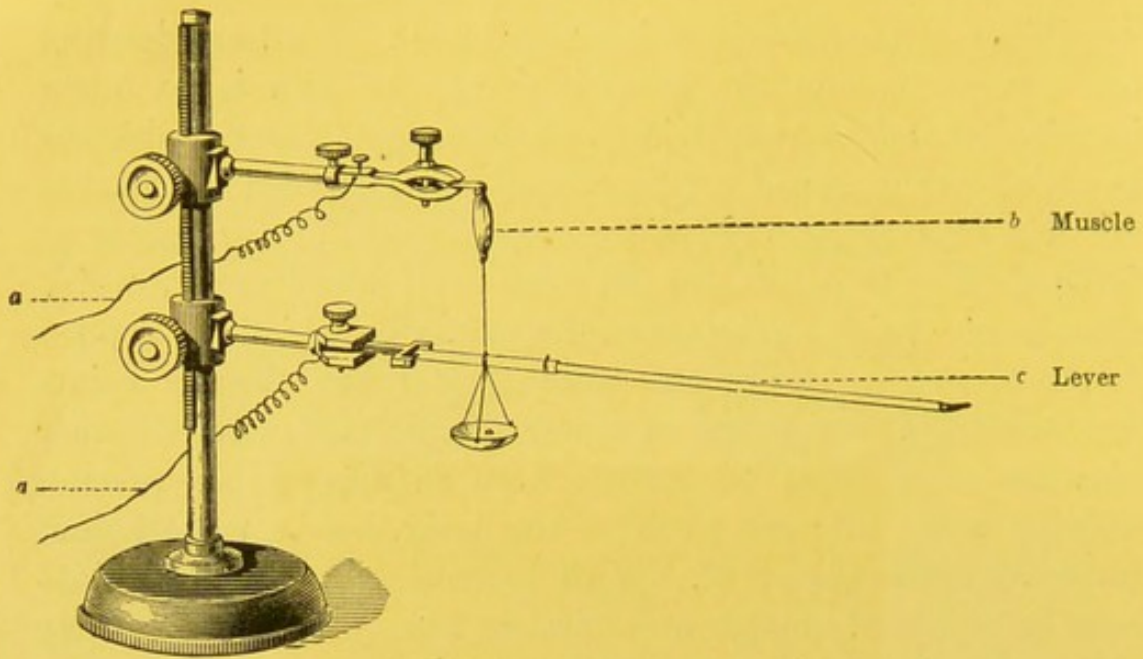
* Tennyson's *Mariana*.

sensibility of the sensations is also blunted. Sight and hearing are less acute, and the sensibility of the skin is so much impaired that Professor Griessbach has found that the distance at which two points of a pair of compasses applied to the skin are felt as a single impression may be used as a measure of fatigue. For this purpose he uses an æsthesiometer, which consists of a pair of compasses, the points of which are applied to the skin at greater or less distances. When the two points are close together they are of course felt as one, but the distance between them must be increased to an appreciable amount, varying with different parts of the body, before two distinct impressions are perceived. With increasing fatigue, the points may be removed further and further from one another before the double impression can be noted. The amount of fatigue can also be estimated, perhaps more accurately still, by the contractile power of muscles, but this takes a longer time. In Waller's dynamograph two handles kept apart by a strong spring are brought together by a grasp of the hand, and the movement is recorded on a slowly revolving cylinder.*

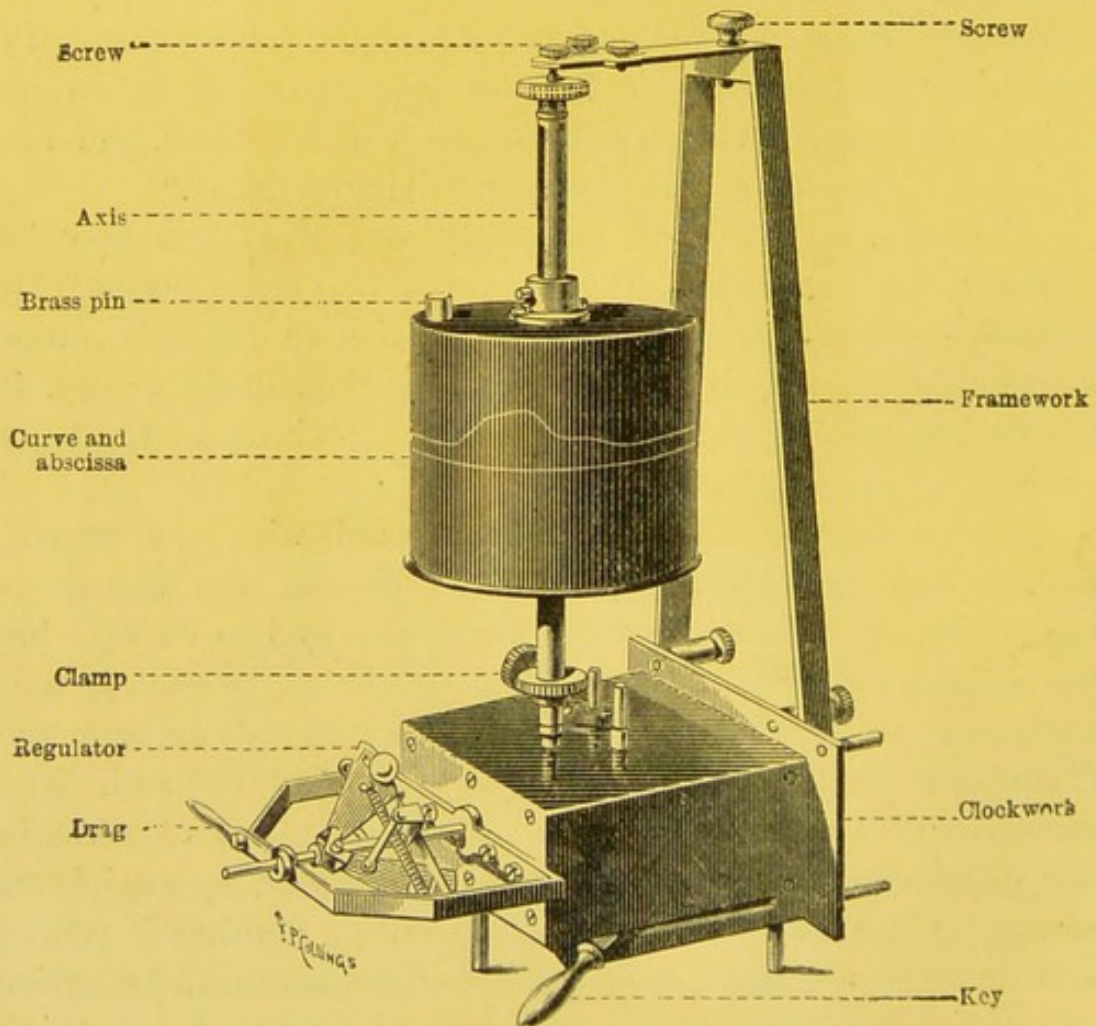
Although, as we shall presently see, weariness may be produced by a number of causes, yet the most frequent is excessive muscular exertion. Over-exertion in a muscle causes it gradually to lose its power of contraction, until, finally, it cannot contract at all, and so movement either of the body or limbs becomes impossible.

But so long as muscles are connected with the central nervous system, the complete exhaustion of the muscle is impossible, for before it becomes paralysed by its own exertion the sensation of fatigue is perceived by the nerve centres, and the nervous stimuli which proceed to the muscle are so much diminished that complete paralysis is never produced. The sensation of fatigue is a central sensation. It is observed in the central nervous system, but it is produced by peripheral causes. One of these is muscular exertion, another is mental exertion. It may seem odd that I should class mental exertion as a peripheral cause of the sensation of fatigue, but I think

* Waller, *Human Physiology*, 1891, p. 339.



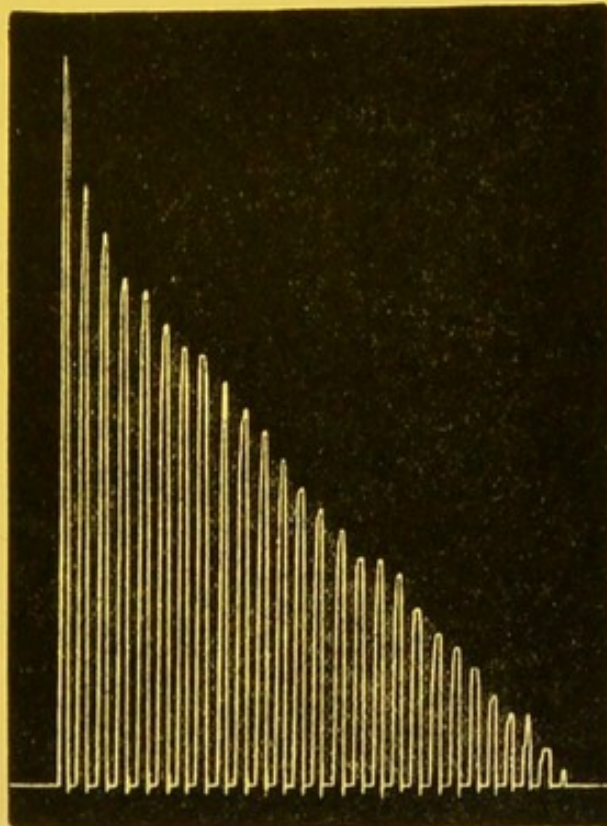
A.—Muscle lever. *a, a*, Wires for stimulating the muscle.



B.—Revolving cylinder on which the lever writes.

FIG. 3.—Recording Apparatus for Muscular Contraction.

it may be properly so denominated, as the part of the brain used in mental work is outside of, or apart from, that part where the sensation of fatigue is perceived. The effect of exertion on isolated muscles has been chiefly examined in the case of the muscles of the frog. One end of the muscle is fixed in the pincers, the other end is connected with a lever which is drawn up by every contraction, and this writes on a revolving cylinder. When the muscle is caused to contract at regular intervals by an electrical stimulus, the



FIGS. 4 and 6.—After Mosso. Exhaustion curve of finger in healthy man where the muscles are caused to contract by electrical stimulation. This curve is so nearly the same as that of an excised muscle stimulated at regular intervals that the same figure does for both.

intensity of which remains the same, the contractions become gradually less and less until they cease (fig. 3). Professor Kronecker has found that when this occurs the tracings of the series differ so greatly in height that their upper limit forms a straight line (fig. 4). A somewhat similar condition is observed in the muscles of man when they are made to contract by the local application of an electrical stimulus (fig. 6). The

apparatus (fig. 5) by which this observation is made is called the ergograph. It consists of a string running over a pulley, and having at one end a weight and at the other a loop, into

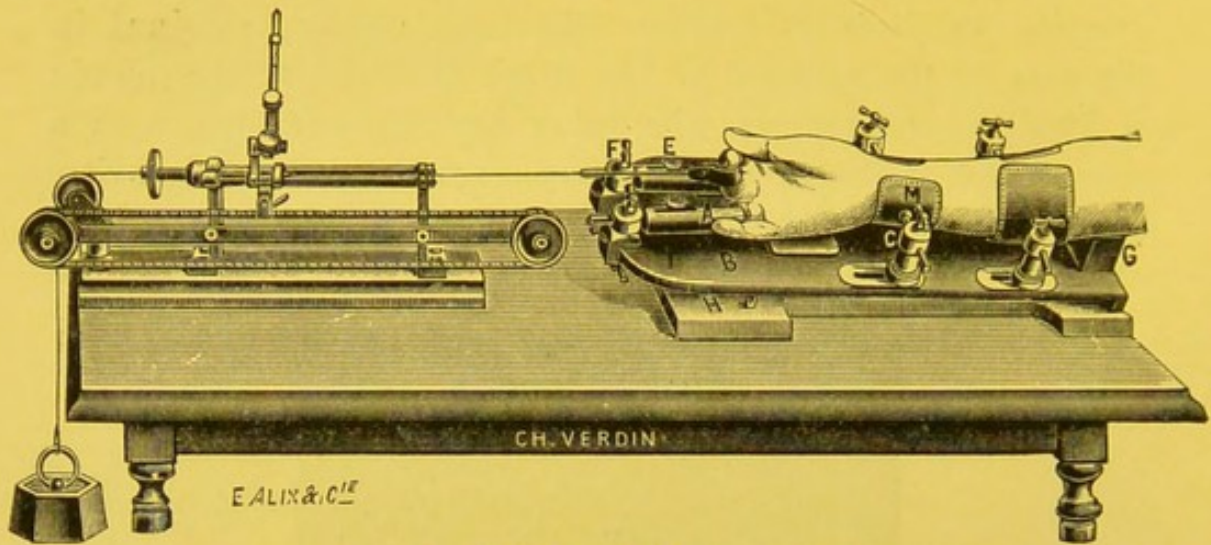


FIG. 5.—Mosso's Ergograph.

which the finger can be passed. Each time the finger is bent the weight is raised, and, by having attached to the string a recording point, tracings can be obtained on a revolving

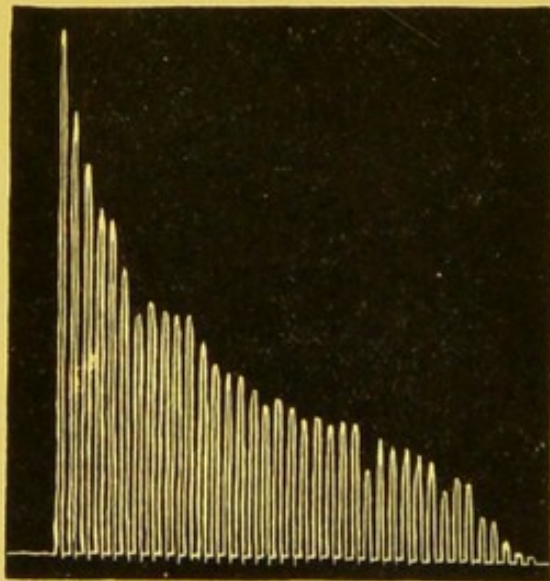
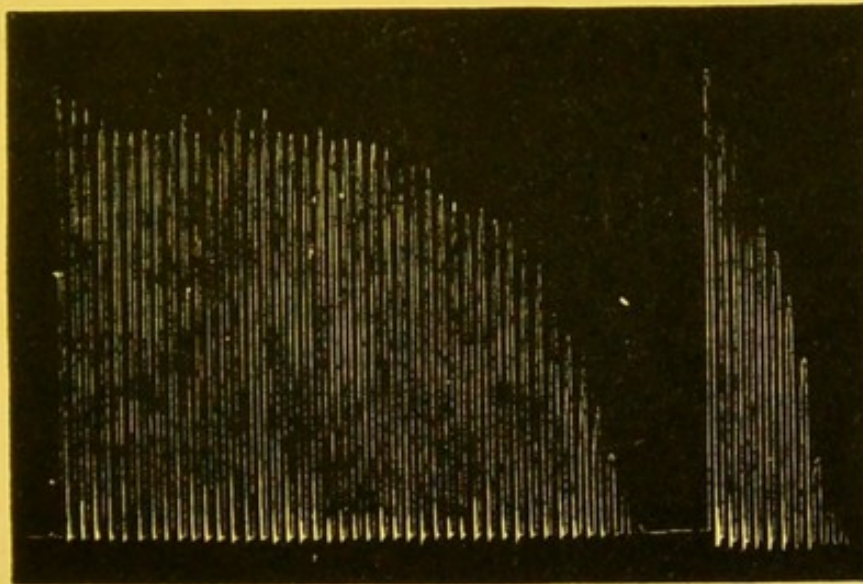


FIG. 7.—After Mosso. Tracing from Dr. Maggiora, showing rapid but gradual failure from fatigue.

cylinder in the same way as was done with the frog's muscle. When the muscle is caused to contract, not by the direct application of electricity to it, but to the nerve supplying it, a

different curve is obtained in which the line of fatigue is not straight, but is curved in a manner which would almost seem to indicate that the nerves become more sensitive to the stimulus before the fatigue becomes complete. This experiment, however, is open to the fallacy that stimulation of the nerve does not act, I think, only upon the motor fibres which go to the muscle, but affects also the sensory fibres which produce more or less painful sensation. The curve of fatigue produced by the stimulation of the peripheral nerve is not unlike that obtained from voluntary muscular



A

B

FIG. 8.—After Mosso. Voluntary Contraction. A, Before conducting an examination. B, After examining 19 candidates.

contractions. But these fatigue-curves vary very much in different persons, and even in the same persons at different times. Thus, in the tracing given by Professor Mosso from Dr. Maggiora, the curve gradually falls quickly from the very beginning of the experiment. In Professor Adducco's it falls slowly at first (as in first part of fig. 8), and very rapidly afterwards, whilst in Dr. Patrizi's it remains nearly at the same level for a long time and then the muscle gives out all at once (fig. 9). The difference between these curves seems to depend upon the comparative development of the

central nervous system, which in fig. 9 sends stimuli of increasing intensity and keeps up the flagging muscle until complete exhaustion sets in. This power of the nervous system over muscle is a matter of common observation in horses, some of which quickly flag on exertion, while others run on until they die. The tracing obtained from Dr. Maggiora with increased strength and better health (fig. 13) approximated more nearly to that of Professor Adducce's.

Fatigue of muscles and their failure to contract are not due, as one would at first suppose, to exhaustion or destruction of their contractile elements, but are really produced by the muscle being poisoned by the products of its own action,

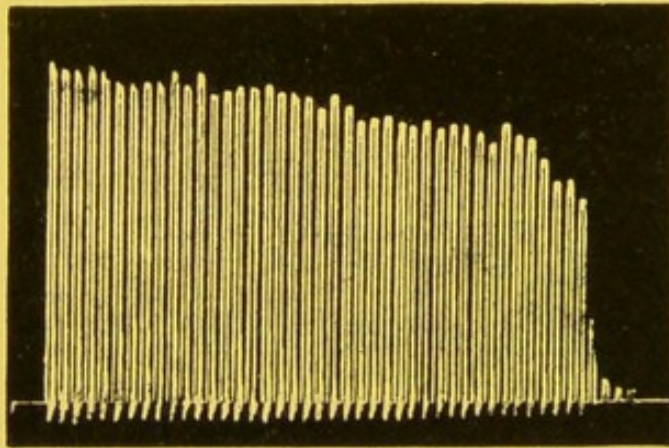


FIG. 9.—After Mosso. Tracing from Dr. Patrizi, showing long-continued movement and abrupt failure.

just as a fire becomes choked by its own ash. If a muscle is made to contract by electrical stimuli until it quite ceases to respond, and the products of its own waste are washed out of it by a current of saline solution being forced through the artery which supplies it, its contractile power is again restored, and the same effect can be produced to a certain extent by massage being applied directly to the muscle, and the products of fatigue being squeezed out of it.

The same effect can be produced in the muscles of an uninjured limb by massage, and the fatigue consequent upon over-exertion can be to a great extent removed by systematic massage (fig. 10).

Provision has been made by nature for what may be called self-massage of the muscles, by which the products of waste are pumped out of the muscle by its own contractions. Each muscle is encased by a hard fibrous covering or fascia, between which and the muscular fibres lies a lymph space. Each time the muscle contracts it squeezes fluid from this space into the lymphatics, and each time it relaxes, it tends to produce a vacuum within the fascia which is filled up by fresh arterial blood, the venous blood and lymph which have been squeezed out being prevented from returning by the valves in the veins and

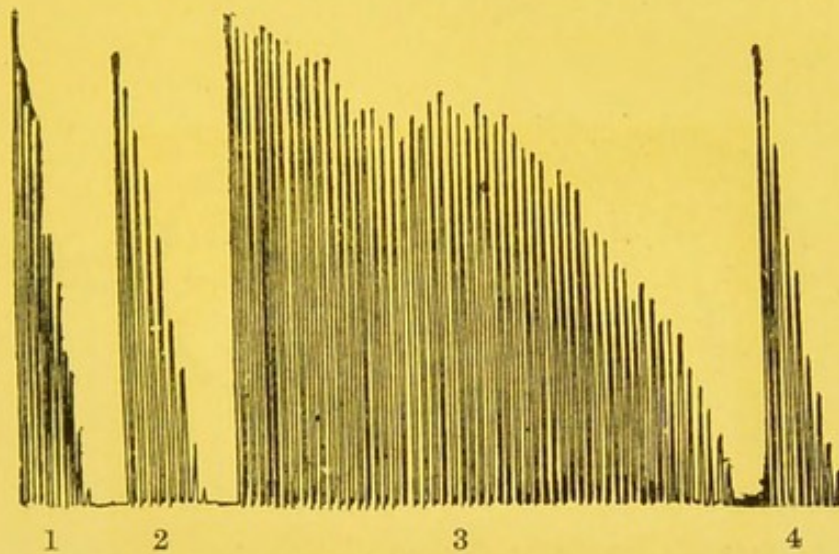


FIG. 10.—Effect of Massage on Fatigue. After Maggiora and Vinaj. *Blät. f. Klin.*, "Hydrotherapie," 1892, p. 6. 1. The fatigue curve of the left hand raising a weight of 3 kilogrammes every two seconds. 2. The fatigue curve of the right hand. 3. The fatigue curve of the left hand after five minutes' massage. 4. That of the right hand without massage.

lymphatics. The more the muscle acts the better is it supplied with blood, and the more thoroughly are its waste products removed. It is in consequence of this that, when an animal or man is stiff with standing, exercise restores the contractility of the muscle and the suppleness of the limbs. But this provision only succeeds up to a certain point, and, by-and-by, more waste products are produced than the pumping apparatus of the muscles themselves can remove. And it appears to be a fact that continued exertion does most harm to the muscle after it begins to get wearied. It is possible that this damage is

of twofold origin, chemical and nervous. So long as the muscle works within its powers, it utilises carbohydrates as the source of its energy, and does not break down any of the proteids of which its contractile substance is composed. But, when the muscles are forced to work after they are wearied, they seem to use up their albuminous constituents. Thus it is that great exertions may be performed without any increase in the urea of the urine, provided that these exertions do not over-fatigue the muscles, but when over-fatigue occurs the breaking up of albuminous tissue is shown by the large increase of urea in the urine.

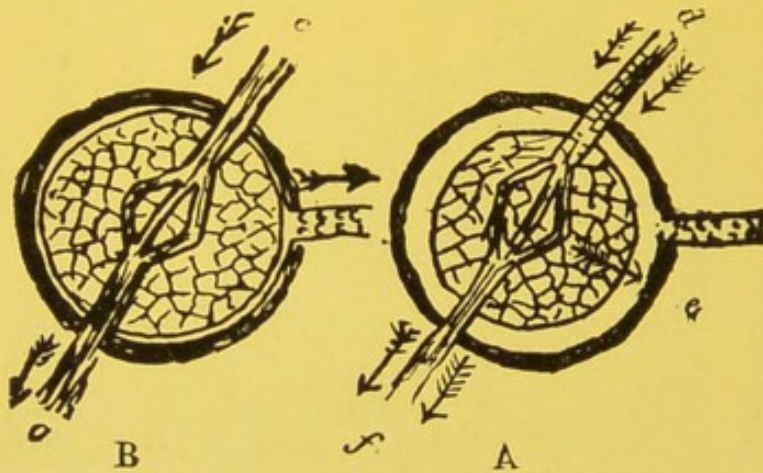


FIG. 11.—Diagram of Transverse Section of Voluntary Muscle, to show the pumping action exerted on the muscle juice and waste products during action. The blood-vessels cross diagonally. To the left (B) the muscle is contracted and presses the two layers of the fascia together, so as to drive the muscle juice out into the lymphatics. To the right (A) the muscle is relaxed and tends to draw the layers of fascia apart and to suck the juice out of the muscle into the lymph space. *c*, Artery. *d*, Artery. *e*, Lymphatics. *f*, Vein. *g*, Vein. The double arrows in (A) are intended to indicate the increased blood flow through the muscle, and the single arrow within the muscle to indicate the passage of fluid from the muscle into the lymph space between it and the surrounding fascia.

A possible cause of nervous injury is this. Professor Sherrington has found that contraction of one muscle tends to cause reflex inhibition of its opponent. If this inhibition should become imperfect, the muscles will to a certain extent work against each other instead of the whole of their force being applied to external work. We can thus see how useful

a provision of nature it is that the sensation of fatigue should be felt long before the muscle itself is exhausted, so as not only to prevent complete paralysis, but also to arrest the continuance of exercise beyond the point up to which the muscles can work without injury.

Mental fatigue is evidenced externally to some extent by muscular weakness, and mental fatigue, like bodily weariness, will cause the eyelids to droop and the muscles to relax. The effect of mental fatigue in lessening muscular power has been beautifully shown by Mosso in some experiments which he

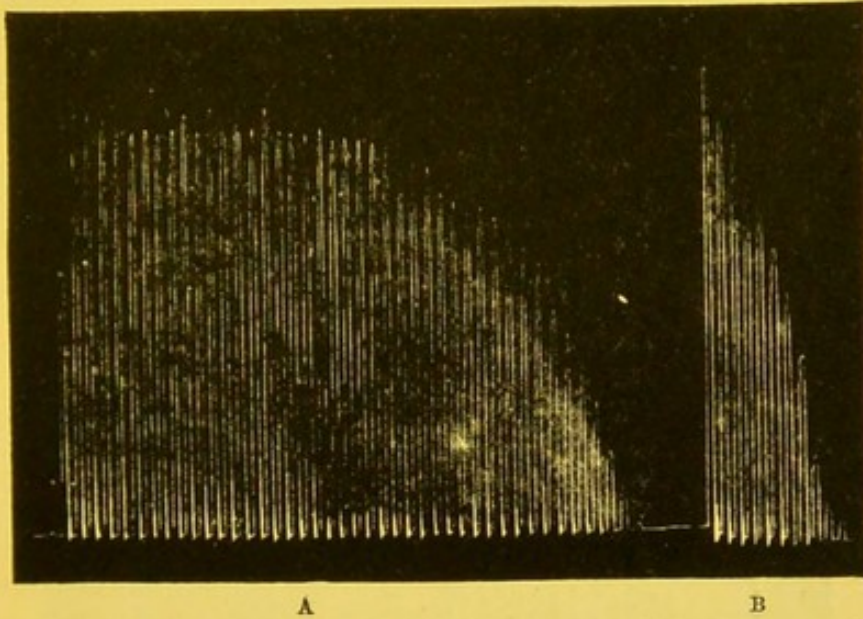


FIG. 12.—Effect of Mental Work on Muscle. After Mosso. Voluntary Contraction. A, Before conducting an examination. B, After examining 19 candidates.

gives in his book *On Fatigue*. A tracing taken by the ergograph, before conducting an examination, shows well-sustained and prolonged muscular energy, but when the second tracing is taken, after examining 19 candidates, the muscular power falls very rapidly and is very quickly exhausted. A similar, but less marked, fall is shown in the mental fatigue of giving a lecture (figs. 13 and 14). One might suppose that this was simply due to the mental exhaustion, but this is not the case, for similar tracings are obtained when the finger is made to contract by electrical stimulation of its flexor muscles—a fact which demonstrates that the mental fatigue has caused

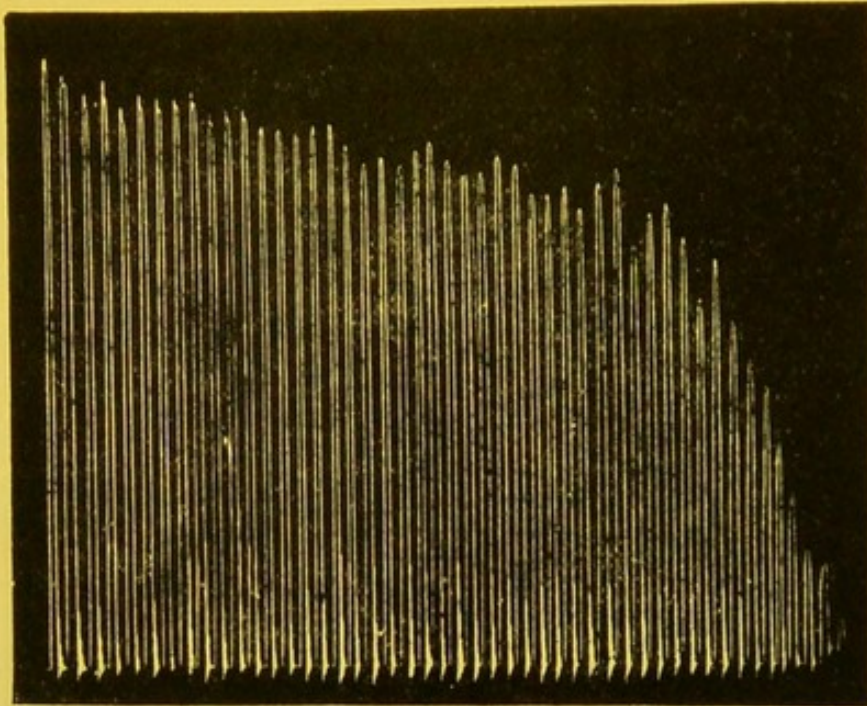


FIG. 13.—After Mosso. Normal tracing from Dr. Maggiora.

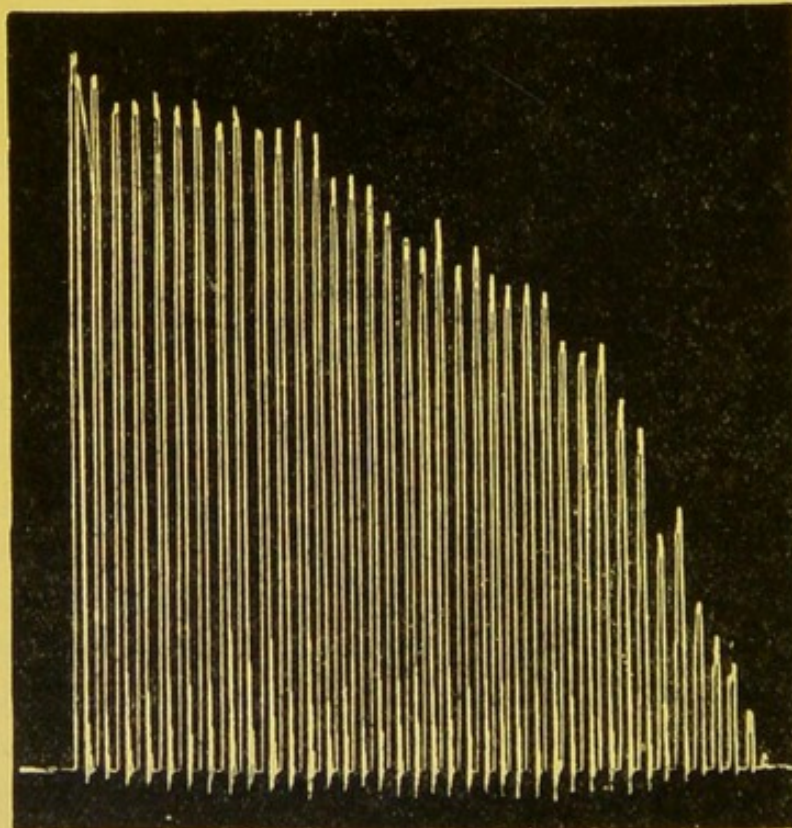


FIG. 14.—After Mosso. Tracing from Dr. Maggiora, when fatigued by giving a lecture.

actual muscular weariness (fig. 15). A similar relation is observed in the brain to the products of muscular fatigue, for lactic acid, which is one of the products of muscular contraction, has been shown by Preyer to have a soporific action. From the experiments I mention it is clear that, in regard to fatigue, the brain and the muscles go together, and that it is a mistake to regard muscular fatigue as a stimulus to the brain, or mental fatigue as a stimulus to the muscles. We must not look upon hard mental exercise as a relief from muscular exercise, nor upon hard muscular exercise as a rest for the

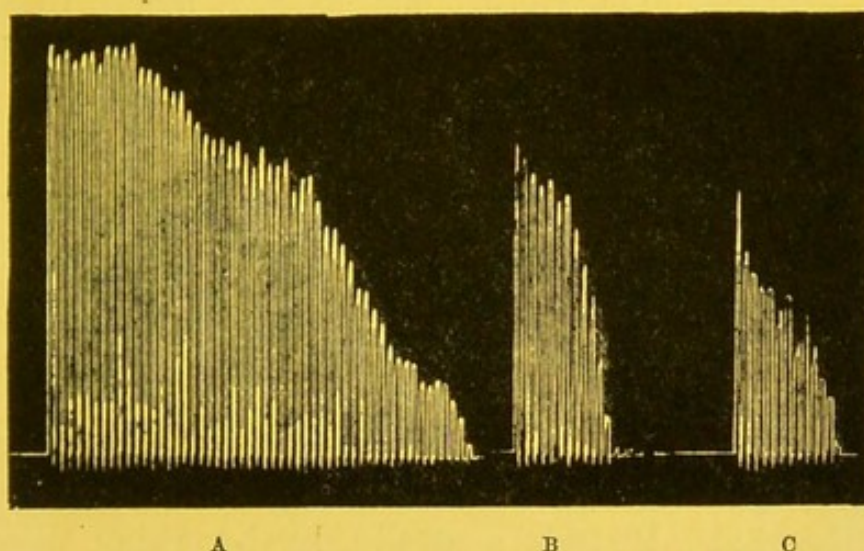


FIG. 15.—After Mosso. Exhaustion Curve from Electrical Stimulation. A, Before examination. B, Immediately after examination. C, Two hours after close of examination.

brain. In saying this I wish to point out that I am speaking here of exhausting work, and that slighter efforts, either of the brain or muscles, when not continued too long, may have a very different effect. But to this point I must again return when considering the effect of exertion upon circulation.

A great deal of the mental work done in schools and offices involves much muscular action, although this may affect only a very small group of muscles, viz., those connected with the eye. The ciliary muscle is in almost constant use, adjusting the focal distance of the lens to the objects looked at, and the extrinsic muscles of the eye are in constant use as the eye

travels to and fro over a page. The closeness of the connection between mental integrity and the visual apparatus was brought before me very plainly several years ago. A gentleman came to me from South Africa complaining that he thought he had a tumour in his brain because his mental powers were leaving him. He had a large business, which he had been accustomed to manage with perfect ease, but now, he said, he looked at his books and could understand them perfectly for four or five minutes. Then, he said, the whole book seemed to get confused, and he could not add the figures together. On testing his eyes I found that, with advancing years, he was becoming presbyopic. When he first looked at his books, he was able, by a great exertion of the ciliary muscle, to focus the figures and see them distinctly, but, in four or five minutes, the ciliary muscle became fatigued, and the figures became blurred, with the result that he thought his mind was giving way. I sent him to an oculist, who had him provided with proper glasses, and he went back to South Africa perfectly well.

The importance of the extrinsic muscles of the eye was impressed upon me by the case of a student at St. Bartholomew's Hospital. He was a steady, hard-working fellow, but could not pass his examination at the London University on account of the severe headaches which always came on shortly before the ordeal. He got glasses which corrected the astigmatism, but he was not improved. I sent him to one of my colleagues, who found that convergence was deficient, and, by providing him with prismatic spectacles, the headaches were abolished, and he passed his examinations with comfort. In ordinary circumstances, the deficiency in convergent power was so slight as not to make itself felt, but, under the strain of reading for an examination, the muscles became fatigued, and his power of steady work was destroyed for the time being.

Even when the eyes are unconscious of external objects, there may be a great deal of optic strain associated with thought, for, when the attention is fixed upon a mental problem, the eyes are frequently kept rigidly fixed upon some

external object, staring at it, although the person does not in the least know at what he is looking.

But the eyes have further a most important effect upon the brain apart from the ciliary muscles. If the two eyes are quite different in focal length, or if one of the eyes is entirely useless, the better eye does all the work and the other does not interfere. But if the two eyes are very nearly, but not quite, equal the brain seems to receive a blurred impression, similar to that which is given to the eye by looking at a piece of print which has shifted slightly in the press. The one mental image seems to interfere with the other, and a person in this condition may read a page of print several times over without in the least understanding its meaning, although when the difference between his eyes is equalised he understands it without effort. In saying this I speak from personal experience. When I was a boy of seven or eight years of age I received a blow from the pellet of a pop-gun on the right eye, which was damaged in consequence. For many years I practically used the left eye, and in reading print I took in the sense without being conscious either of the letters or the words. One day, however, in reading some proofs I found that a change had occurred in me of the most disquieting nature. I no longer took in the sense, I laboured over the words one by one, and it was only after reading a short article three or four times over that I could make out the sense. The reason, as I afterwards found, was that the left eye was beginning to fail, so that the two eyes were nearly on a par. After a short time, the left eye became much weaker than the right, which then took up the running, and I again read with ease as before. During part of the time when the difference between the two eyes was slight, I had it corrected by glasses, but when the difference became very marked on account of the greater failure of the left eye, the glasses were no longer necessary, the right eye sufficing for the work.

Images starting from the brain itself may obscure those which are entering the sensorium through the eye, and every one knows how visions of a football or cricket match in the

afternoon may obscure the Greek or Latin images conveyed by the eyes to the sensorium in the forenoon by the pages of class books. By means of a powerful effort these disturbing mental images may be banished, and attention concentrated on the work before one, but when fatigue, either of body or of mind, or ill-health occurs, this becomes less and less possible. There seems to be a slight analogy between these mental images and the images which occur in the eye after gazing at an object. These after-images remain much longer in debilitated than in strong persons. The power of recuperation in the eye and rapid adjustment for new images probably depends to a great extent on the rapidity with which the blood circulates through it. This is certainly so to a great extent with the brain, in which, as Mosso has shown, the circulation varies

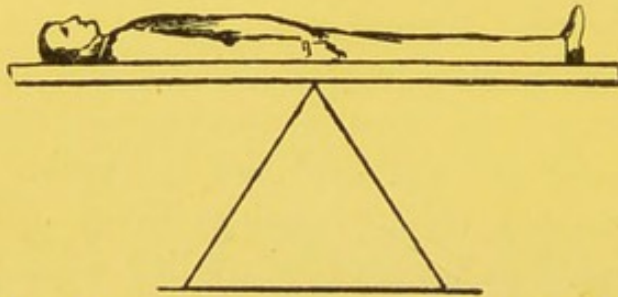


FIG. 16.—Mosso's Table Balance for Weighing Thought.

very quickly, and to a great extent with the functional activity of the organ. To such an extent is this the case that Mosso was able to "weigh thought," if we may use the expression. He constructed a large but very delicate balance on which a person lay. When the mind was quiet the balance was in equipoise, but whenever the person began to think the head went down on account of the greater quantity of blood going to it for increased thought. In a man who had lost a part of his skull he was also able to observe alterations in the brain, and he observed that thought caused the cerebral vessels to dilate. Vaso-motor nerves are said by some not to exist in the cerebral vessels, and it is therefore possible that this rapid change of calibre depends upon chemical changes in the brain itself, but whether the variations in the cerebral circulation occur through the medium of vaso-motor nerves or not is a matter of com-

paratively slight importance, for the variations do exist, and the amount of cerebral work is very closely dependent upon the vascular supply. This was shown by Mosso, who found that long-continued muscular exertion renders the brain anæmic, and impairs its functional activity to such an extent that quails, after a long flight, are unable to see objects in front of them, and are killed by dashing against them. A personal experience of my own, which I have already related somewhere else, gave me a curious light upon the relation between mental work and cerebral circulation. Many years ago I used to write for a medical periodical. On returning home one day, after a very heavy day's work at the hospital, and feeling completely exhausted, I found a note from the editor, "Please let me have an article on such and such a subject to-night." I sat down with pen and paper before me, but not a word could I write. Then I lay back lazily, and began to speculate as to the cause of my want of ideas. I thought "The brain is the same as it was yesterday, but yesterday I was not tired; perhaps it is the feebler circulation that prevents the brain from acting. If the blood does not go up to the brain, I may bring the brain down to the blood." I therefore placed my head flat on the table, looking sideways at the paper, and began to write easily. On raising my head again every idea fled, so I placed my head again down on the table, and finished the article with my head in that position. A similar instance was afforded by the practice of the late Mr. W. G. Lecky, the historian. He had, as every reader of *Punch* knows, a large magnificent head, mounted upon a long neck and a willowy body. He found out that his circulation was not sufficiently strong to raise the blood to his brain in sufficient quantity for its functional activity in the upright position. A mutual friend informed me that he wrote his *History* lying upon the sofa. I was so much interested in the question that I asked Mr. Lecky himself. He told me that this was a mistake, that he did not lie down, but actually wrote kneeling on a sofa which had a large broad head to it. This served him for a writing table, and, in this kneeling position, he wrote all his works, the blood having thus to travel to his brain in a horizontal line, instead of upwards against

the force of gravity as it would have had to do in the sitting position.* Involuntarily people adapt their position to the intensity of their brain functions, so that a man engaged in argument is apt to bring his head forward and downwards into a position in which the blood can be driven more freely into the cerebral vessels by the heart.



Some LECKY-daisical attitudes!

FIG. 17.—Mr. Lecky in various attitudes. (With the kind permission of the proprietors of *Punch*.)

The necessity of the circulation through the spinal cord for its functional activity is shown by the well-known experiment of Stenson, who showed that, if the aorta of a rabbit is compressed for a few minutes by the finger, the whole of the lower

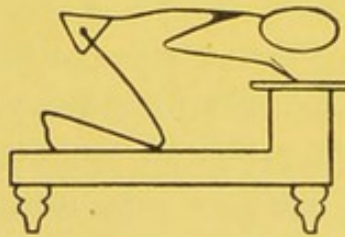


FIG. 18.—Diagram of the position assumed by Mr. Lecky when at work.

limbs and the lower half of the body become completely paralysed, and it is only a certain time after the re-establishment of the circulation that motor power is regained. There is, therefore, a very close connection indeed between muscular work,

* Mr. Lecky gave me permission to publish this fact.

mental work, and the activity of the heart and muscles. To this we may add also the respiration. If one hurries up a stair, one is very likely to arrive at the top out of breath, and with

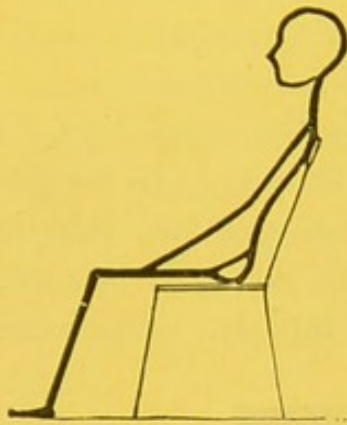


FIG. 19.—Attention.

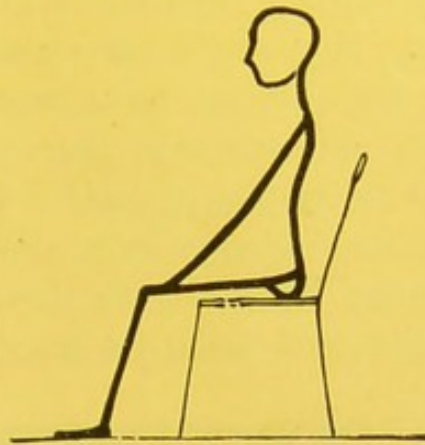


FIG. 19.—Interest.

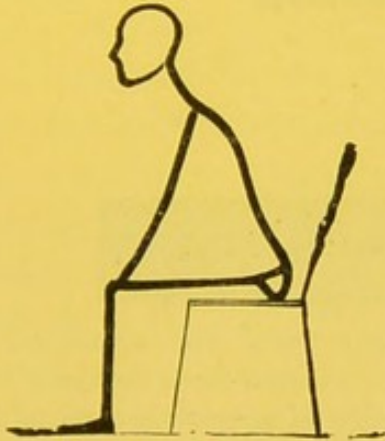


FIG. 21.—Eagerness.

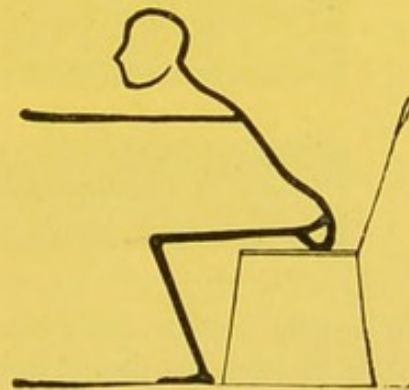


FIG. 22.—Excitement.

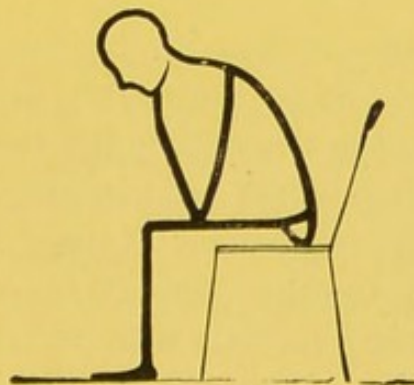


FIG. 23.—Reflection.

the heart beating very much more quickly than usual. One might be inclined to attribute these phenomena to the blood having been pumped very quickly through the body by muscular action and to stimulation of the nerve centres in this

way. But this is not the case, for the quickened pulse and rapid respiration are produced by the action of the products of muscular waste on the nerve centres. This was demonstrated by Mosso at the International Congress of Medicine in Berlin, in 1890. If a dog is narcotised with opium, and the blood of another dog that has been kept quiet is injected into its veins, no alteration occurs in the respiration or circulation. But if the nervous system of another dog is stimulated by an electrical current, and tetanus is produced even for two minutes, its blood, when injected into the sleeping dog, will accelerate its respiration, and make its heart beat rapidly. This is not due

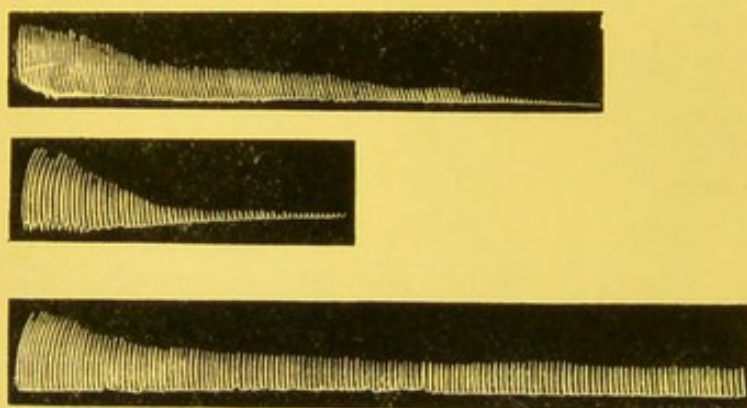


FIG. 24.—After Weichardt. Effect of fatigue toxins and antitoxins. The upper tracing is that of normal muscle. The middle is that of a muscle poisoned by fatigue toxins. The lower is that of a muscle whose endurance is augmented by fatigue antitoxins.

to carbonic acid but to actual toxins, because when the blood is stirred up with air, so as to thoroughly arterialise it, it still retains its effect upon the circulation and respiration.

Toxins, which can produce fatigue, can be separated from exhausted muscles by expression of their juice. Not only is this the case, but by treating albuminous substances derived both from vegetables and animals with reducing and oxidising agents, and by reduction of tubercle bacilli, Weichardt obtained the same toxins as from exhausted muscles. When these are injected into animals they cause the muscles to become soon exhausted upon exertion. He was, however, also able to produce an antitoxin, which had the effect not only of counteracting the fatigue toxin, but of gradually prolonging the

endurance of the muscle.* There is a curious resemblance between the effect of toxins produced by fatigue and the venom of the cobra, which was shown by Sir Joseph Fayrer and myself† to have a paralysing effect upon the spinal cord, the motor nerves, and the muscle itself, and they also resemble cobra venom in the fact that Weichardt obtained his fatigue antitoxins in the same manner as Fraser and Calmette obtained anti-venins. Fraser found that by injecting a small dose of snake venom into a horse, using at each time only enough to produce slight symptoms, he was able to increase the amount until fifty times the fatal dose could be injected without doing any harm.

The serum of a horse, thus treated, when injected into an animal poisoned by snake venom, prevents death unless the dose of the venom is too great. I have myself seen two rabbits poisoned by similar doses of cobra venom. Into one Professor Calmette injected the anti-venin serum, while the other received no treatment, and, in about half an hour, the one which had received the serum was alive and well, while the other was dead. The symptoms produced by Weichardt's toxins are very nearly the same as those of snake venom, and his antitoxin neutralises the toxin, either when mixed with the toxin before or when injected simultaneously with it.

A curious point in regard to fatigue, and possibly associated with the formation of antitoxins in the body is, that after a walk of four or five miles intense weariness sometimes comes on, but if the person continues to walk in spite of it the weariness gradually passes off and may not return, although the person continues to walk the greater part of the day. Many years ago I noticed in my own case that after a walk of four or five miles I felt more fatigue than if I had walked twenty.

The effect of food in the stomach as preventing, or relieving, fatigue is very extraordinary. Many years ago I took a walking tour with my friend, Dr. Mitchell Bruce, in the Austrian Tyrol,

* W. Weichardt, *Münchener Med. Woch.*, 1906, p. 7.

† Brunton and Fayrer, *Royal Society's Proceedings*, No. 149, 1874, pages 92 and 93.

and we made the discovery that we could entirely prevent fatigue by taking food every two hours. We thought this was entirely new, and intended to publish it on our return home, but one day, while taking lunch on a moraine in the middle of a glacier, we turned up the pages of Baedeker, and found, amongst others, a recommendation to this effect. Alpine guides are thoroughly aware of it, and usually make climbers eat every two hours, whether they wish it or not. The effect of food thus taken in removing fatigue is so rapid that it seems hardly possible for absorption to have occurred, and for the food to be carried to the muscles. It is, I think, not improbable that the action is an indirect one. The work of the muscles appears to be carried on, like that of the glands, to a great extent by means of enzymes or ferments, and many years ago I separated from muscle a glycolytic ferment. I obtained it, however, in a small quantity, and my experiments on muscles are very like those of Corvisart upon the pancreas. Corvisart succeeded in obtaining a proteolytic ferment from one pancreas, but he experimented on hundreds of others before he could obtain it again. The reason was that the proteolytic ferment is only contained in an active form in the pancreas during digestion. During fasting, it is present in the form of an inactive zymogen. Starling has found that the zymogen is converted into an active enzyme by a secretion formed in the intestinal wall, and it has been found also that an enzyme in muscle is rendered active by a similar secretin-like body formed by the pancreas. But Pawlow has shown that saliva, or even water, in the stomach stimulates secretion of the pancreas through its nerves, and thus one can readily understand how food taken into the stomach can not only act, but act very rapidly, upon the muscles, the chain of action being—(1) food in stomach stimulates the pancreas, (2) this produces a stimulating body, which (3) is absorbed by the blood, (4) passes to the muscles, (5) renders their enzyme active, and so (6) increases their power.

The exact chemical nature of fatigue toxins has not yet been determined, but I think it is quite likely that they may be nearly allied to ammonia or to compound ammonias.

When the isolated muscle of a frog is fatigued by over-exertion, irritation applied to its motor nerve ceases to cause contraction before the muscular fibre itself has become completely exhausted, and while direct irritation of the muscular fibre by electricity will still cause it to contract. Although the sensation of fatigue is first felt in the nerve centres, it next affects the peripheral ends of nerves, and lastly the muscles. In a research (fig. 25) I made many years ago upon the action of ammonia on muscle and nerve, by aid of a grant from the Royal Society, I found, amongst other things, that salts of ammonium have exactly this action on muscle and nerve, viz., that they greatly lessen the contractility of the muscle, but that they destroy its power of responding to

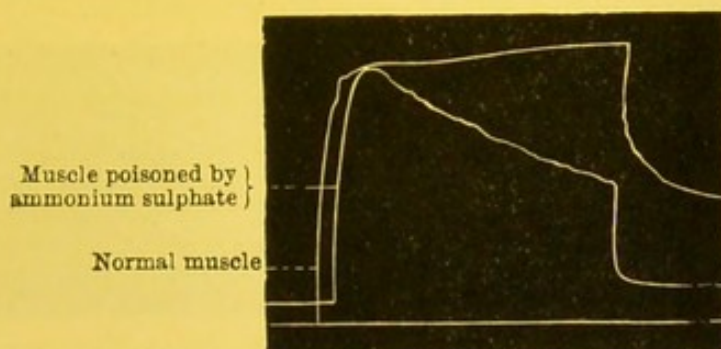


FIG. 25.—Tetanus tracing to show the paralyzing action of ammonium sulphate on muscle. At first the contractions are nearly equal, but that of poisoned muscle quickly falls, whilst that of the unpoisoned one slightly rises.

electrical stimulus supplied to its motor nerve before the muscle itself is exhausted. They sometimes do this in a very peculiar way. The first stimulus applied to the nerve causes the muscle to contract just as much as an unpoisoned muscle, but the second stimulus applied to the nerve has sometimes no effect. It seemed as if the first stimulus had destroyed the end-plate of the motor nerve in the poisoned muscle, and that this prevented any further action of the nerve just as too powerful a current may break down a fuse, and thus completely terminate the connection between an electric lamp and the source of electricity which should cause it to glow. My experiments were not published *in extenso*, only a short abstract having appeared in 1881, and the facts that I have just mentioned were not recorded in it, but in my text-book on

Pharmacology.* They are, I think, interesting, not only in relation to fatigue but to the pathology of the somewhat rare disease, myasthenia gravis, in which the ends of the motor nerves of the muscles seem to be affected somewhat in the same way as after poisoning by ammoniacal salts (fig. 26).

In healthy people, the ingestion of food is usually followed by increased power of work, but in some people a sensation of overpowering fatigue comes on some little time after a meal. This is often very marked about one and a half hours after breakfast, and it sometimes leads patients to have recourse to stimulants in order to get them through the day's work. This weariness is evidently of a toxic nature, and is probably due to faulty metabolism in the intestine or liver.

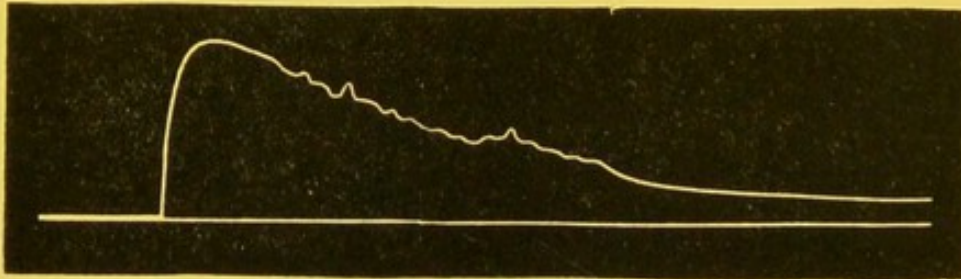


FIG. 26.—Tetanus tracing to show the paralyzing action of amylamine on muscle.

In a paper in *The Practitioner*, 1880, on "Indigestion and Nervous Depression," I considered this weariness to be probably due to the absorption of unchanged albumoses, in which case the seat of faulty metabolism would probably be the intestinal wall, where they ought to be built up into albumens; but if they are of the nature of ammoniacal salts, or compound ammonias, the seat of deficient metabolism would be the liver, which has the power of converting certain ammoniacal salts into urea. But the power of the liver to destroy toxins is not entirely confined to ammoniacal salts, for Bokenham and I found that the liver had the power of destroying the toxic properties of diphtheria toxin which was circulated with the blood through the vessels of an isolated liver. We can therefore, see how faulty metabolism in the digestive organs

* *Text-book of Pharmacology*, 1886, p. 567.

may be responsible for a great deal of fatigue. In addition to this, toxins may be directly formed by certain pathogenic micro-organisms.

The bacillus coli seems to have a special power of producing fatigue toxins, and many people in whose intestines it exists in great abundance suffer from constant weariness. When they go to bed at night they are tired, when they rise in the morning they are tired, and their complaint often is the one that I mentioned at the beginning of this article, that they are "always tired."

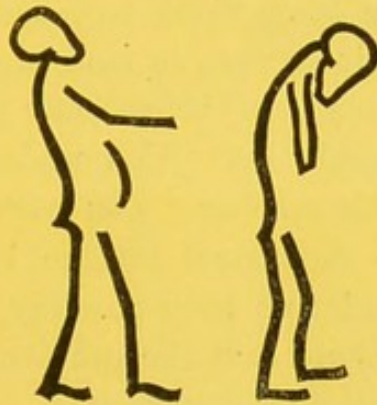


FIG. 27.—The Pharisee and the Publican. Mental exhilaration and mental depression.

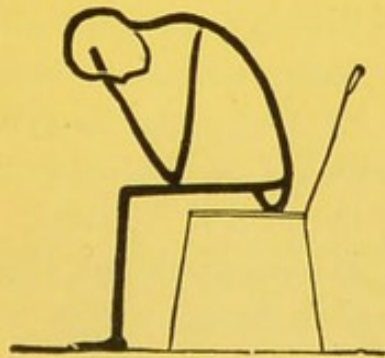


FIG. 28.—Grief.

Another form of weariness is that of emotional fatigue. Depressing emotions, such as worry or sorrow, may produce both an expression of weariness and a sensation of weariness. I have observed in my own case that sometimes the expression of weariness was observed by others before I perceived any sensation of it myself. Some years ago, I used frequently to wonder why people said to me "How tired you are looking," when I was unconscious of any feeling of fatigue, but

experience showed me that, when this remark was made, I was feeling sad or worried, and that often a feeling of exhaustion or fatigue came on from these emotions, so much so that by-and-by, when I felt tired without apparent reason, I began to think over what had happened to worry or sadden me, and I generally made out some depressing cause. Curiously enough, the effect of sadness or worry may be sub-conscious, and the persons who are its subjects may hardly perceive any emotion, and only become conscious of the sensation of weariness (figs. 27 and 28).

I do not know that it is right to assume that in nervous Americans worry produces fatigue more readily than in others, but it would almost seem so, if we may judge from the fact that they very commonly say "You make me tired," instead of saying "You trouble me" or "You worry me." One of the curious things about emotional fatigue is the rapidity with which it comes on, and this may possibly be explained by the fact that Weichardt found that the gray substance of the brain yielded a fatigue toxin of great power.

While weariness may be produced by the direct action of chemical substances on the brain itself, on the motor nerves, and upon the muscles directly, we must always remember that a part is played by the circulation, both in supplying the substances necessary for functional activity, and in removing fatigue-producing bodies. I have already mentioned the effect of posture in regard to mental activity, and in some feeble persons bodily quiet is necessary for the purpose of mental processes. Mark Twain's horse, which was so feeble that it seemed as if it wished to lean up against a post to think, is not alone in its peculiarities, for they are shared by some human beings. The common observation that it is difficult to do any hard mental work immediately after a full meal, and that if mental work is persisted in indigestion is apt to come on, was explained nearly two centuries ago by Mayo, who supposed that all the functions of the body were carried on by a number of sprites to which the name of "vital spirits" was given. When these spirits are up in the brain, he said, they cannot be down in the stomach, and, if they are down in the stomach,

they cannot be up in the brain, and so digestion and mental work cannot be carried on at the same time. If we replace the term "vital spirits" by "blood" we get an explanation of the process very nearly correct in terms of modern physiology. In the same way I have already mentioned that violent exercise renders the brain anæmic and incapable of work, and yet we know that a certain amount of exercise not only keeps the body, the muscles, and the digestive organs in good condition, but also helps the brain to do more work

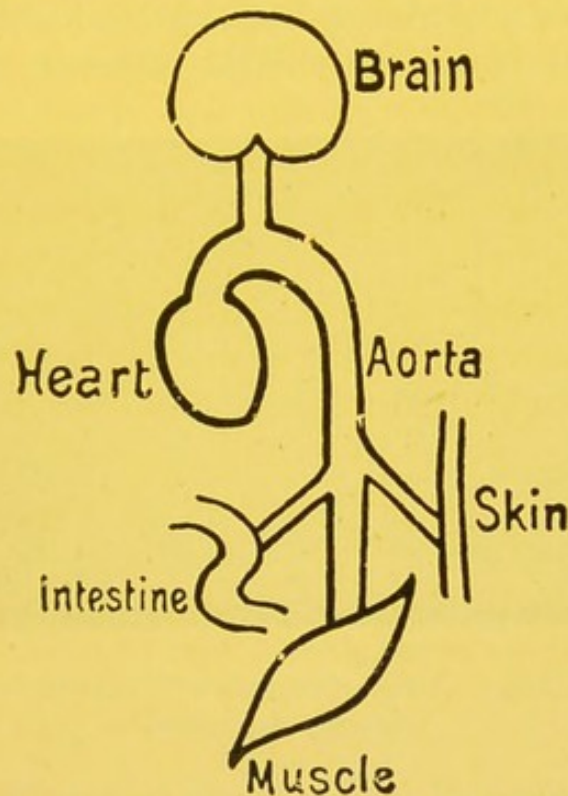


FIG. 29.—Diagram showing the four great areas for the distribution of blood in the body, viz., the muscles, the brain, the intestine, and the skin.

(fig. 29). The reason of this is, I think, twofold. First, that the blood supplied to the brain is of a better quality, and secondly, that it is in larger quantity. When children have been out at play, they may for a few minutes after their return to the schoolroom be less able to think, and find application to their lessons more difficult than before they went out, but the play has not necessarily done them any harm. After the momentary effects of the muscular exercise have passed off, stimulation of the heart still remains, and the accelerated circulation soon becomes diverted from the muscle to the brain

itself, and thus better work will be done than if the children had had no opportunity for play. But care must be taken that the play does not lead to exhaustion, with more or less permanent anæmia of the brain on the one hand, or strain of the heart on the other. It has been shown by Schott that severe strain will produce temporary dilatation even in a healthy heart, and clinical experience has shown that if this strain is frequently repeated, especially if the heart is enfeebled in any way, the dilatation becomes more or less permanent.

From my own experience I should be inclined to say that cardiac dilatation is especially liable to occur in children who

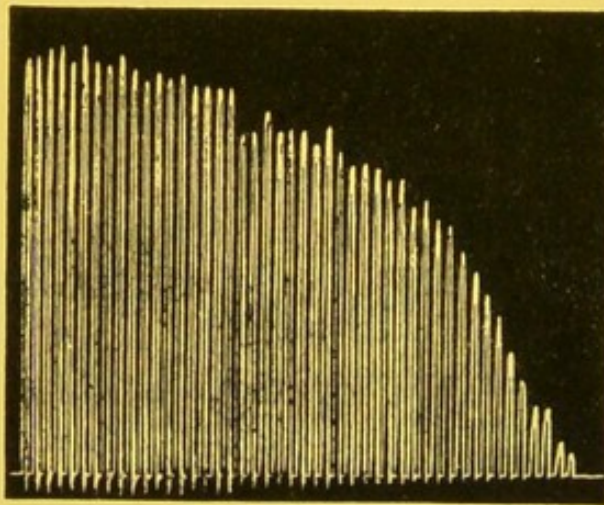


FIG. 30.—After Mosso. Exhaustion curve of finger in healthy man from voluntary movement.

are growing quickly, and in whom the muscular system of the limbs has grown out of proportion to the strength of the heart. The exercise which would be just sufficient to produce enjoyment and health in one child may in another give rise to weariness and exhaustion, and even to permanent damage. This is one of the reasons why systematic physical exercise in schools could not be introduced with safety until medical inspection had been made compulsory, for, without medical examination, the exercise, while doing good to a number, might be most prejudicial to a few. This was brought very forcibly to my notice a short time ago by a doctor who brought his daughter to me for examination. She was a tall, healthy girl, apparently very strong, and well developed. He told me that

only a short while before she had been appointed games mistress at a school to teach gymnastics and athletics, and he was horrified to discover that shortly afterwards she developed a well-marked mitral murmur, and, unfortunately, I was able to confirm his observations when I examined her heart. The risk of over-strain and the ill-effects of over-fatigue, both in regard to the muscles of the limbs and of the heart, become greatly lessened by training, and Mosso has found that after training the amount of work done by the ergograph may be doubled before exhaustion sets in, as is shown by the accompanying tracings (figs. 30 and 31), and the experience of training for all athletic contests shows that not only do the muscles become

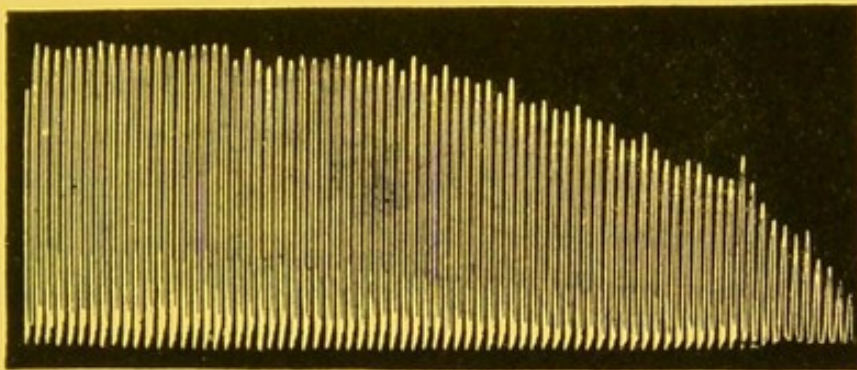


FIG. 31.—After Mosso. Showing the effect of training in increasing endurance as compared with Fig. 30, from the same person. Owing to a difference in the apparatus the height of the curves is not comparable. The amount of work done was really double that in Fig. 30.

stronger and less easily fatigued, but that the heart acquires additional strength, so that the exertion, which would at first have produced excessive dyspnoea, or even collapse, may at the end of a course of training be undertaken, not only without discomfort, but with actual pleasure. In the present state of our knowledge, we cannot precisely say in what training consists, but, in view of Weichardt's experiments, it seems not unlikely that the body becomes accustomed, not only to produce fewer fatigue toxins during exertion, but also to form fatigue antitoxins; and this seems all the more likely because the process of training must be carried on in exactly the same way as that of producing anti-venins, *i.e.*, the increase in the dose, either of the exercise or of venom, must be very gradual

indeed. The best example of training that I know of, is that of the famous wrestler Milo of Crotona, who was enabled to carry a full-grown bull on his shoulder by beginning to carry it when it was a new-born calf. Day by day he carried it, and day by day, as its weight increased, his strength increased in proportion, so that at last the task, which in other circumstances would have been impossible, was accomplished with ease. Where fatigue is due to depressing emotions, we cannot hope to remove it entirely in the same way; but it is



FIG. 32.—Egyptian Ladies Playing at Ball. From a painting in a tomb about 3,500 years old. The first three figures have balls in each hand, and the third appears to be throwing them backwards for the fourth and fifth to catch. The tenth lady is throwing balls for the seventh to catch, both of them being mounted on others. (Cailliaud, *Recherches sur les Arts et Métiers*.)

quite possible that, by training the muscular system, antitoxins may be formed which will render the person more able to bear worry or sorrow, even although the conditions which produce these emotions may be incapable of removal. Where weariness and inability to work depend upon a feeble heart, the heart may be strengthened by graduated exercise, by strophanthus or digitalis, or strychnine and caffein, and by the use of iron, if anæmia is present at the same time. It is not to be forgotten that calcium is a powerful cardiac tonic, and that a

certain amount of it, combined with other things, may greatly help their action. In considering the use of games, and especially in comparing them with systematic gymnastic exercises, it must always be carefully borne in mind that pleasure is a powerful stimulus both to the nervous system and the circulation, and therefore such games or exercises as give pleasure should always have the preference. Amongst all games those of ball have been favourites from the earliest times, and they not only give pleasure and exercise the muscles, but they tend to increase the power of co-ordination, which is of much more value than simple muscular power (fig. 32). In the chronic weariness which is due to intestinal toxins we also frequently give the remedies which I have just mentioned as cardiac tonics, and these may act upon the intestines themselves directly, or may act indirectly on them through the improved circulation. We may give artificial aids to digestion, such as pepsin and pancreatin, and Metchnikoff's treatment by administering the bacillus lactici acidi, or milk acidified by it, sometimes succeeds in curing some cases of weakness and depression which have resisted ordinary treatment. In many cases of chronic intestinal catarrh we find alternate constipation and diarrhœa, and in such cases we ought to give intestinal antiseptics as well as cardiac tonics. A very interesting problem may yet turn out to be the relationship between intestinal toxæmia and the statement which has been put into the mouth of the unemployable British workman, "I eats well, I drinks well, I sleeps well, but when I sees a job of work coming along, I'm all of a tremble."

Faint, illegible text, possibly bleed-through from the reverse side of the page. The text is arranged in several paragraphs, but the characters are too light and blurry to transcribe accurately. Some faint markings, possibly numbers or symbols, are visible on the right side of the page.

