Physiology. — *"On the consumption of oxygen by the nervous system."* By F. J. J. BUIJTENDIJK. (Communicated by Prof. Dr. H. ZWAARDEMAKER).

(Communicated in the meeting of October 29, 1910).

By means of a method that I demonstrated at the 8th International Physiological Congress I succeeded in determining the quantity of O_2 absorbed from a fluid by a removed animal tissue. In the below mentioned experiments the brain, the spinal cord, or some other peripherical nerves were placed in a RINGER solution, of which after some time the percentage of O_2 was determined. By means of the method applied and the apparatus used, the experimental error could be reduced to 2—3 mm.^{3} O_2.

WINTERSTEIN [1]) determined the consumption of O_2 of the frog at 260—300 mm.^{3} per hour and gram, whilst at an equal temperature muscles of the same experimental animal consume 80—100 mm.^{3} O_2 per gram and hour (THUNBERG [2])).

I can also verify this strikingly high consumption of O_2 by the central nervous system. So I found that the spinal cord of a frog in a RINGER fluid consumed 180—250 mm.^{3} O_2 whilst for the muscles likewise $\pm$ 80 mm.^{3} was found. Fishes proved to be very fit experimental animals for the study of the assimilation of the brain. KULIABKO [3]) succeeded in transfusing such a fluid through the brain of fresh-water-fishes so that the respiration motions continued. Consequently this fluid is especially fit to make life continue in the removed brain of fishes.

I used for my experiments fresh-water-fishes as Esox lucius, Lucioperca sandra, Tinca vulgaris, Idus melanotus, Perca fluviatilis, for which I could always find a solution of salt which, during the transfusion through the brain, according to the method of KULIABKO, caused the motions of respiration to return. For the consumption of O_2 by the brain of salt-water-fishes I simply used a solution of NaCl with an osmotic tone like that of the experimental animal (according to the indications of BOTAZZI) [4]), I had at my disposal specimens of Gadus morrhua, Gadus merlangus, Trigla etc.

The figures for the brain originating from newly killed animals do not differ much. Some of the results are mentioned in the first

[1]) WINTERSTEIN, Zeitschr. f. Allgem. Physiol. 1907 blz. 315—392.
[2]) THUNBERG, Scandin. Archiv. für Physiol. Bd. 17.
[3]) KULIABKO, Archiv. intern. de physiol. IV p. 437.
[4]) BOTAZZI, Ergelnisse der Physiol.

column (*A*) of Table I. In the second column (*B*) are mentioned the quantities of O_2 consumed by the brain of fishes that had died in the aquarium a few hours previous to the experiment.

TABLE I.

Quantity of O_2 consumed per gram and hour by the brain of fishes.

A.		*B.*	
1. Idus melanotus	124 mm³	1. Trygon pastinaca	39 mm³
2. „ „	103 „	2. Lucioperca sandra	36 „
3. „ „	117 „	3. Idus melanotus	23 „
4. Perca fluviatilis	127 „	4. Gadus morrhua	34 „
5. Tinca vulgaris	110 „		
6 Gadus merl.	84 „		
7. Trigla hirundo	94 „		

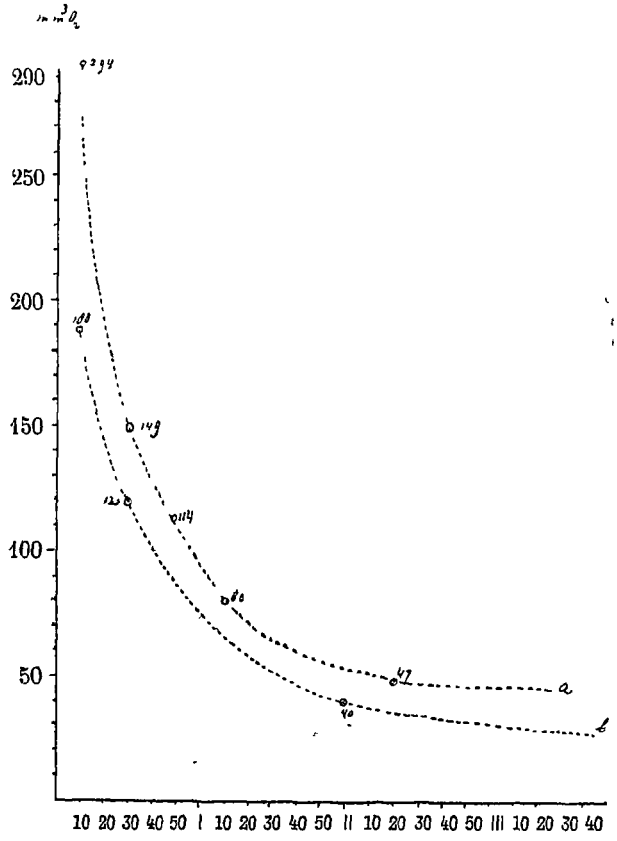
Besides the figures mentioned in the table I still obtained some results being much lower, and amounting e. g. to no more than 9 or 6 mm.³ O_2 per gram and hour. An equal consumption of O_2 by the brain was likewise ascertained even 48 hours after the death of the individual, and is consequently only an accessory respiration according to BATELLI.

During the investigation it appeared to me that the percentage of O_2 of the fluid (at the beginning saturated with air) should not be less than 3 cc. O_2 per liter. If the latter was the case, the quantity of O_2 consumed by the tissue was considerably reduced.

Another fact that must be taken into account, is the mortification which takes place even when the fluid is of a good composition. So the brain of Perca fluviatilis consumed, during an experiment lasting 30 minutes, 184 mm³ O_2 (calculated per gram and hour). After having been kept during an hour between two watch-glasses, the result was 162 mm³ O^2 (for an experiment of 30 minutes). With another specimen these figures were respectively 173 mm³ O_2 and 145 mm³ O_2. One sees that the diminution of the consumption of O_2 by mortification in the first hours need not be of importance in the tissues of such cold-blooded animals. The quantity of O_2 consumed is however considerably reduced if the fluid is repeatedly renewed (e. g. after every 20 minutes).

In fig. 1 I have given a graphical representation of two of these experiments.

Fig. 1.



On the line of the abscisses the time is indicated that has elapsed since the beginning of the experiment, in the ordinates the quantity of O_2 per gram and hour. Curve *a* relates to the respiration of the brain of a Gadus merlangus, curve *b* to an experiment with an Esox lucius. One sees that the diminution of the consumption of O_2 is constantly going down by repeated renewing of the fluid. In how far this must be attributed to the extraction of vital (oxydative) ferments I wish for the present moment to leave undecided.

In a subsequent series of experiments I examined the quantity of O_2 that was consumed by the lobi optici, the lobi olfactori and the cerebellum conjointly, and likewise the quantity of O_2 consumed by the radix cerebri, and the medulla longata, originating from the same experimental animal. In all the experiments mentioned in table II, the consumption of O_2 by the radix ceribri was found

to be considerably smaller than by the remaining part of the brain The duration of the experiments was always the same (20-25 minutes) the final percentage of O_2 3—4 cc. per liter.

TABLE II.

Quantity (per gram and hour) consumed by the radix cerebri (column *A*) and by the remaining part of the brain (column *B*).

A.	*B.*
1. Idus melanotus 133 mm³	202 mm³
2. Trigla hirundo 160 „	177 „
3. Gadus merlangus 64 „	84 „
4. Cyprinus carpeo 136 „	200 „
5. Tinca vulgaris 43 „	66 „

Had I tried hitherto to compose the fluid in which the brain respired in such a way as to preserve the normal qualities of the nervous system, I have likewise investigated some injurious influences, and these experiments give an impression of the part that the vital processes take in the consumption of O_2. The experiments of Table III show that ether, aqua distillata, and a little acidity of the solution of salt considerably reduce the consumption of gas whilst a little increase of alcalicity is only connected with a slight reduction.

TABLE III.

Quantity of O_2 (per gram and hour) consumed by the brain from a RINGER fluid (column *A*) and from another fluid (column *B*).

A.	*B.*
1. Scardinius erythropht 133 mm³	Sol of ether-salt 37 mm³
2. Idus melanotus 202 „	„ „ 84 „
3. Clupea harengus 44 „	„ „ 4 „
4. Tinca vulgaris 31 „	„ „ 3.5 „
5. Scardinius erythropht 124 „	Aqua dist. 43 „
6. „ „ 70 „	„ „ 34 „
7. Lucioperca sandra 72 „	$^1/_{100}$ N.HCl 19 „
8. Gadus merlangus 84 „	$^1/_{100}$ N.KOH 64 „

Some electrodes had been placed in the glass vessel in which the brain respired in the midst of the fluid, so that, during the experiment the tissue could be irritated by induction currents.

In the first place I can communicate that in the controlling experiments the solution of salt only or with the pieces of blottingpaper immerged in it did not show a reduction of the percentage of O_2 worth mentioning, if during 30—60 minutes induction currents (of the strength used for the irritation) were conducted through the fluid. It was however different, if the fluid contained brain. In table IV is shown that brain respiring strongly consumes considerably more when irritated. On the contrary hardly any increase is observed with brain respiring feebly (dead brain). In the first three experiments the consumption of O_2 after the irritation is stated.

TABEL IV

Quantity of O_2 consumed (per gram and hour) by the brain (column *A*) with irritation during 20—30 minutes (column *B*) and afterwards (column *C*).

	A	*B*	*C*
1. Lucio perca Sandra	208 mm.^{3}	275 mm.^{3}	229 mm.^{3}
2. Tinca vulgaris	110 „	150 „	98 „
3. Gadus morrhua	67 „	87 „	— „
4. „ „ [1])	23 „	28 „	— „

In connection with the current view about assimilation in the nervous system, the increase of consumption of O_2 demonstrated here, is not unexpected.

For the investigation of the consumption of O_2 by peripheric nerves, I used the head nerves of large specimens of Gadus morrhua, as with these experimental animals each individual gave a sufficient quantity of nervous tissue to consume such a quantity of O_2 from the RINGER solution as could easily be determined. Every experiment lasted 30—60 minutes.

I have given a graphical representation of the results in fig. II.

The ordinate indicates the quantity of O_2 consumed (per gram and hour), the abscis the experimental numbers arranged in a special way. It is evident that with irritation (indicated in the figure by *) the

[1]) For Rana I find for the spinal cord a consumption of 150 mm.^{3} O_2 with irritation 178 mm.^{3} O_2, afterwards 141 mm.^{3} O_2 per gram.

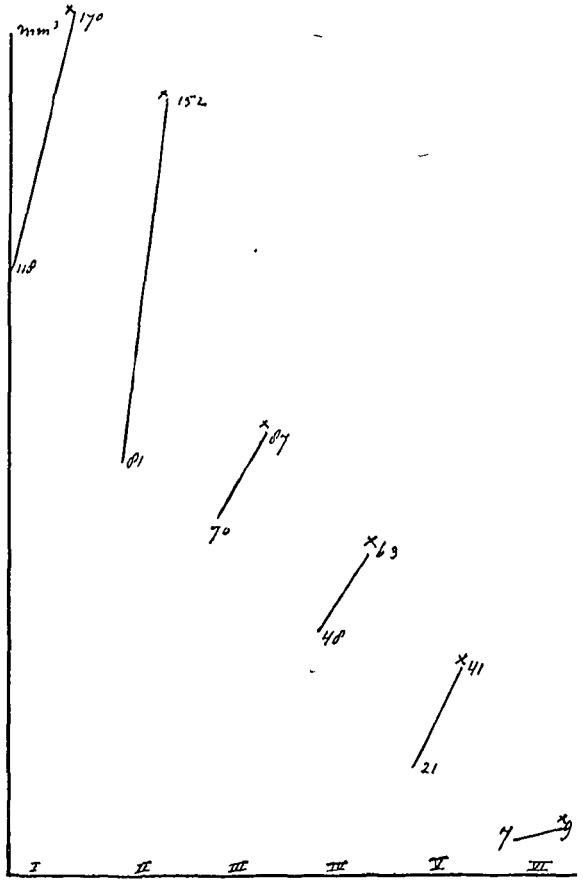


Fig. 2.

quantity of O_2 consumed is greater, and has increased in proportion as the quantity originally consumed is greater [1]).

By the kind coöperation of the Director of the Kon. Zoöl. Gen. Natura Artis Magistra, to whom I beg to pay here my sincere thanks, I was able to execute these investigations.

[1]) For the frog-nerve I could not possibly show an increased consumption of O_2 during irritation. In the following table stands under column *A* the quantity of O_2 consumed by Nervi ischiadici of Rana, under column *B* during irritation.

	A.	*B.*
1.	64	66
2.	48	52
3.	35	31
4.	23	25

The slight differences fall entirely within the experimental errors.