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Physiology. — *"On the consumption of oxygen by cold-blooded animals in connection with their size."* By Mr. F. J. J. BUYTENDIJK. (Communicated by Prof. T. PLACE).

(Communicated in the meeting of March 27, 1909).

The tables of the majority of investigators prove that in cold-blooded animals the consumption of O_2, as well as the production of CO_2 per kilogram of weight of the animal, is more considerable with small than with bigger animals of the same kind.

As an example I quote some figures from POTT [1]).

Rana temporaria (old)	weight	13.9	gr.	CO_2	p.	K.G.	and hour	180 cc.
„ „ (young)	„	1.26	„	„	„	„	„ „	648 cc.
Bufo variabilis (old)	„	15	„	„	„	„	„ „	220 cc.
„ „ (young)	„	3.6	„	„	„	„	„ „	770 cc.

KUNKEL [2]), on the other hand, in an accurate investigation of Limax variegatus, found proportionality with the volume.

The experiments with fishes of JOLYET and REGNARD [3]), BAUMERT [1]) and others nearly always proved the more intense respiration of the smaller animals.

Thus e.g. according to JOLYET and REGNARD the consumption is:

	Weight	O_2 p. K.G. hour	temp.
	Gr.	Cc.	
Cyprinus auratus	33.40	45.8	12°
„ „	82.130	35.03	12°
On the other hand by Muraena anguilla	51	40.5	14°
„ „	112	48	15°

More recent investigations of ZUNTZ (1901) [3]) with an apparatus constructed by himself lead him to the following conclusions, among others: "Die Grösse des auf die Gewichtseinheit bezogenen Verbrauches (von O_2) ist bei kleinen Fischen erheblich grösser und geht annähernd proportional der Körperoberfläche, ein weiterer Beweis dafür dass diese Beziehung nicht durch das Bedürfniss der Erhaltung der Eigenwärme zu erklären ist."

(The amount of oxygen consumed, referred to the unit of weight,

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1) According to ZUNTZ in HERRMANN's Handbuch der Physiologie Bd. IV, 2 S. 129—154.

2) KUNKEL, Verhandl. Deutsche Zööl. Gesellsch. Bd. 10 p 22—31.

3) ZUNTZ, Verhandlungen der Berliner physiol. Gesellschaft XIII, 1901.

is with small fishes considerably greater and is approximately proportional to the surface of the body, another proof that this relation is not to be explained by the necessity of preserving the heat of the body).

These experiments, as far as I could gather from the short paper, were made with carp [1]). Also KNAUTHE [2]) experimented with this fish in ZUNTZ' laboratory. From his table it appears that the CO_2 production and the O_2 consumption of $2^1/_2$ year old carp is even somewhat greater than of $1^1/_2$ year old animals. His further experiments concerning the N-metabolism taught him "dass nicht die grössten sondern mittelgrosse Thiere den geringsten N-Umsatz zeigten."

("That not the largest, but medium-sized animals showed the greatest N-metabolism)."

VERNON [3]) determined the O_2 consumption in invertebrate sea-animals and also gives a table in which the weights of the experimental animals are mentioned. Some figures are repeated here.

	Weight	Average O_2 value at 16°
Rhizostoma pulmo	62.2	0.0167
	69.6	0.154
	87.1	0.083
	93.	0.106
	107.	0.060
Carmarina hastata	15.2	0.088
	27.6	0.065
	30·2	0.100
	30.7	0.129
	34.5	0.085
	44.8	0.088
	54.7	0.078

The rest of the table shows several deviations from a constant decrease of the O_2 consumption with the size, as is also the case with Carmarina. The author thinks that perhaps "the preservation of osmotic equilibrum between the tissues of the organism and the external medium may need the continuous application of vital energy and as the smaller the animal the larger the proportionate surface exposed a larger respiratory activity would necessarily result."

[1]) The "Landwirthschaftlichen Jahrbücher", which were to publish more detailed accounts, I could not get at.

[2]) KNAUTHE. Arch. f. d. ges. Physiol. 73, S. 490—501.

[3]) VERNON. Journal of Physiology vol. 19 no. 1 1905.

2. The method followed by WINKLER[1]) to determine O_2 in water is sufficiently accurate to follow the O_2 consumption of marine animals. In short it comes to this: whilst the air is entirely shut off a strongly alkaline JK solution and $MnCl_2$ is added to the liquid to be examined. The precipitate that is formed is, after settling, dissolved with HCl. The iodine that has been set free, titrated with $^1/_{100}$ norm. thiosulfate, yields with the aid of a simple formula (given by WINKLER) the quantity of O_2 per Litre.

That this method gives sufficiently accurate results, appears e. g. from the following experiment:

Scyllium canicula:

Weight	temp.	Duration of the experiment	O_2 consumption	O_2 per hour and KG.	Difference
24 and 25 gr.	12.13°	1 hour	2,55 c.c.	52.04	0,78
id.	13°	2 hours	5,02 „ .	51,26	

In the following tables the O_2 consumption is calculated per hour and M^2. In order to convince myself, that the area of the animals may be said to be approximately proportional to the $\sqrt[3]{\text{weight}^2}$, I defined the area of some sharks by the following method.

The killed fish was dried in filter-paper and weighed. Then it was immersed in melted paraffine (50°), taken out and allowed to dry and cool, after which it was weighed anew. Now in different places of the animal bits of paraffine were taken off (pieces as flat as possible), so that the skin was laid bare. These pieces were weighed and measured (with millimetre-paper) and the average weight of 1 mm.^{2} of the layer of paraffine was determined. Thus I found:

Weight scyllium	Weight with paraffine	Paraffine	Weight 1 mm^2. paraffine	Area in cm^2.	$\sqrt[3]{\text{weight}^2}$
9.9	11.65	1.65	0 5	33	4.64
108.270	114 850	6.580	0.36	183	22.7

With the small scyllium, therefore, $\sqrt[3]{\text{weight}^2}$ has to be multiplied by 8, with the large animals by 7, in order to get the area.

3. The experiments with Scyllium cassicula were made in a sufficient quantity of water in diffuse daylight, the sharks lying

[1]) WINKLER, Berichte d. Deutschen Chem. Ges. XXI, 2 p. 2843.

quiet on the bottom (not to mention an occasional movement) and breathing calmly. The duration of the experiments varied; the values of table I refer only to those cases when the animal after the experiment behaved quite normally. For in too long continued experiments asphyxiation sets in and the O_2 value becomes too small.

TABLE I.

Weight in grams	Cc O_2 per hour and individual	Cc O_2 per hour and K.G.	$\sqrt[3]{\text{weight}^2}$	Area	Cc O_2 per hour and M^2.
14	0 87	62.1	5 81	46.48	190.4
24	1.26	52.5	8 32	66.56	189.4
150	4.9	32.7	28.2	197.4	247.7
215	8.16	38	35.9	251.3	324.7
260	9.63	37	40.8	285.6	323.4

From the publications of MONTUORI [1]), who in different fishes stated the diminution of the O_2 consumption with the temperature of the water, I borrow the following scattered figures about Scyllium canicula.

Weight	Temp.	Cc O_2 per K.G. and hour	Temp.	Cc O_2 per K.G. and hour
200	14°	45	32°	22.88
39.5	14°	60	25°	40
11.8	12°	126.38	26°	51.61 or 74.77 [2])

If from these observations the consumption per M^2 is calculated for the same temperature, we find:

TABLE II.

Weight in grams	Temp.	$\sqrt[3]{\text{weight}^2}$	Area	Cc O_2 per hour individual	Cc O_2 per hour and M^2.
200	14°	34.2	239.4	9	375.9
39.5	14°	11.58	92 64	2.37	355.8
39.5	25°	11.58	92.65	1.58	170.6
11.8	26°	5.18	41.44	6.09 or [8.82]	147 [or 213]

1) MONTUORI. Zentralblatt für Physiologie Bd XX n°. 8.
» Gazetta Internazionale de medicina Anno IX 1906.
2) Differs in the German and the Italian publication.

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It seems to me that we are not entitled to conclude from these figures that the O_2 consumption is proportional to the surface.

Tables I and II only prove that the small Scyllium consume more O_2 than the big ones and that, calculated for the weight, this difference is most considerable with the smallest animals, without, however, reaching such a value as to become proportional to the area.

As to the cause of the greater intensity of respiration with smaller animals, it is in the first place the influence of the movements that should be considered. For these are quicker with smaller individuals (also with warm-blooded ones); moreover, in these experiments, the movement through the water will depend not only upon gravitation but also upon the friction at the surface.

The Scyllium, to be true, are during the investigation nearly always at rest. That also the tonus of the smaller animals is larger I venture to surmise a priori. In the second place the difference in age should be considered, which plays an important part also with mammals.

4. Probably very slowly growing animals, which during the experiments remain perfectly motionless, are the Scorpaena ustulata.

The experiments made with these had the following result:

TABLE III.

Weight in gr.	Cc O_2 p. hour individual	Cc O_2 p. hour and K.G.
8	0.38	.47.5
21	0.9	45
55	2.5	45.5

With these animals as well as with the following I was unable to determine their surface. It appears, however, from Table III that the figures per K.G. and hour are about the same.

5. As to the influence of the movements on the O_2 consumption, I may say that a Crenilabrus occilatus, swimming regularly in broad daylight, consumed 0,56 Cc O_2 per hour, 0,365 in the dark, when the animal was not nearly so active.

I then compared two nearly full-grown individuals of Crenilabrus occilatus and Crenilabrus pavo in the dark.

TABLE IV.

	weight	O_2 per hour and individual	O_2 per hour and K.G.
Crenilabrus occilatus	10	0,365	36,5
„ pavo	180	5,13	29,4

With a proportion of 1 : 18 in weight the O_2 consumption is in ratio of 1,24 : 1. With Scyllium a ratio of 1 : 18,5 agreed with a diminution of 1,7 : 1. Eliminating in the experiments with the Crenilabrus the influence of age, we could not help introducing other influences (movements, differences of species).

6. In connection with the above-mentioned experiments of VERNON I also investigated the O_2 consumption in a few individuals of Octopus vulgaris and of Echinus. Here it was my intention to compare two cold-blooded animals, one having a very active metabolism and a very rapid growth [1]), the other consuming very little O_2. In broad daylight the three Octopus individuals just caught, were quiet, their respiration was regular, after the experiment the animals were entirely normal. The smallest Octopus remained during the experimental period in a corner of the bottle and kept very quiet, the larger ones now and then put out a tentacle.

TABLE V.

	Weight in gr.	Cc O_2 per hour and individual	Cc O_2 per hour and K.G.
Octopus vulgaris	10	0 52	52
	110	3.01	27.36
	370	6.1	17
Echinus	45	0.106	2.3
	20	0.034	1.70

I may as well remark here that also Rhizostoma must have a very rapid growth, as animals of 2 or 3 K.G. may occur and the lease of life of these pelagic animals is not long. Carmarina, on the other hand, in which the difference in O_2 consumption is much less dependent on the size, not nearly reaches such a size (at most ± 100 gr.) and has not such a rapid growth.

The figures of my tables, like those of VERNON, show therefore

[1]) Dr. LO BIANCO was so kind as to give me information about this.

in my opinion that the O_2 consumption of the small animals is considerably larger than that of the bigger ones of the same kind. This difference is, I believe, to be attributed to the influence of the more rapid motions of the smaller animals and the more intense metabolism which a growing body possesses. TIGERSTEDT [1]), therefore, rightly says that in general, where assimilatory processes take place, they are accompanied by active dissimilatory ones. Here also belongs without any doubt the observation of WARBURG [2]) that the O_2 consumption after fertilisation of the eggs of the sea-hedgehog increased by 6 and 7 times the amount. The action of light, osmotic pressure and liquid-pressure, which might cause a certain influence of the area on the respiration, has not been settled. The influence of light I have not been able to separate from variation of motility.

Naples, Febr. 8, 1909.

Microbiology. — *"The decomposition of uric acid by bacteria."* By Mr. F. LIEBERT. (Communicated by Prof. M. W. BEIJERINCK).

(Communicated in the meeting of April 23, 1909).

1. *Historical.*

The first investigators who studied the decomposition of uric acid by the action of bacteria were FAUSTO and LEONE SESTINI [3]).

They observed that uric acid in water when exposed to the air did not change, but that, as soon as the mixture was inoculated with a drop of rotting urine, the uric acid totally disappeared in some days.

Only when the experiment was interrupted before all the uric acid had been converted, they could detect urea.

Their conclusion was that the course of the process might be represented thus:

$$C_5 H_4 N_4 O_3 + 3\,O + 8\,H_2 O = 4\,NH_4\,HCO_3 + CO_2$$

whereas as intermediate products alloxan and urea should occur, which latter substance they could really detect, but the former not. They have not worked at all with pure cultures.

The result obtained by E. GÉRARD [4]) was that two processes took place simultaneously.

1) Handbuch der Phys. Nagel. Bd. 1 2e Halfte 2e Heft.

2) WARBURG, Hoppe Seyler Zeitschr. f. Phys. Chem. Bd. 57 blz. 1.

3) Landwirtsch Versuchsst. 1890, Vol. XXXVIII, p. 157.

4) Comptes rendus T. 122, p. 187 et T 123, p 185.