Huygens Institute - Royal Netherlands Academy of Arts and Sciences (KNAW)

Citation:

Buytendijk, F.J.J., About exchange of gases in cold-blooded animals in connection with their size, in:
KNAW, Proceedings, 13 I, 1910, Amsterdam, 1910, pp. 48-53

The polar conic of a point of inflection possessing the inflectional tangent as component part, this replaces according to § 2 two of the tangents out of the inflectional point to the envelope of the harmonic quadruples; this curve therefore touches the inflectional tangents of γ^4 in the inflectional points. '

Indeed, this follows also from the fact, that no tangent of γ^4 can bear a harmonic group unless its point of contact is inflectional point.

5. If U and V are the points of contact of a double tangent of γ^4, then as $(a_u + \lambda a_v)^4 = 0$ shows, $a^3{}_u a_v = 0$ and $a_u a^3{}_v = 0$ are satisfied; each of those points is then the point of intersection of the polar line and the polar cubic of the other point

If we allow U to describe the curve γ^4 then p_u and $p^3{}_u$ touch each other in U and *their point of intersection describes a curve of order* 32. For, p_u and $p^3{}_u$ describe respectively systems with index 12 and 4, since the poles of the polar lines and of the polar cubics passing through a point V are generated on γ^4 by $p^3{}_v$ and p_v. On a right line the two systems determine a (4,36) correspondence and as γ^4 belongs twice to the generated locus, the locus of the point of intersection of p_u and $p^3{}_u$ is a curve γ^{32}.

In each point of contact of γ^4 the line p_u and curve $p^3{}_u$ have three points in common; therefore γ^4 is osculated there by γ^{32}. The remaining 56 common points of the two curves are evidently the points of contact of the 28 double tangents of γ^4.

Physiology. — *"About exchange of gases in cold-blooded animals in connection with their size."* By F. J. J. BUYTENDIJK. (Communicated by Prof. H. ZWAARDEMAKER).

In a previous communication [1]) I have been able to prove that in fishes as well as in a number of invertebrate sea-animals the consumption of oxygen of the smaller individuals is considerably larger than that of the larger ones of the same kind.

Through the kindness of the Director of the Royal Zoological Society "Natura Artis Magistra" at Amsterdam I have been enabled to examine the gas-exchange of a great number of cold-blooded animals, in order to see whether the phenomenon stated in sea-animals occurs also in amphibia and reptilia.

The older investigations of REIGNAULT and REISET [2]), MOLESCHOTT,

[1]) These Proc. XII p. 48.

[2]) REIGNAULT and REISET, Annales de Chimie et de Phys 1849. Vol. 26. p. 299.

Pott and others [1]) concerning the exchange of gases in the lower vertebrata include only few kinds of animals and had not been made in connection with my question. A series of experiments made with animals of different weight, is given by KREHL and SOETBEER [2]), who examined calorimetrically the warmth given off by some animals.

They found at a temperature of 25,3° C.

Lacerta   weight   110 gr. produces per hour and K.G. 0.8 calories.
Rana mugiens ,,   600 ,,   ,,   ,,   ,,   ,,   ,,   0.5   ,,
Alligator   ,, 1380 ,,   ,,   ,,   ,,   ,,   ,,   0.3   ,,
Uromastix   ,, 1250 ,,   ,,   ,,   ,,   ,,   ,,   0.26 ,,

They thought they had to explain these contradictory values and especially the change of the numbers with the temperature from the differences in the kinds of the sample-animals and thought they ought to attribute the higher production of warmth in the first two animals not to their smaller dimensions but to their manner of living in the temperate zone, while they found that the protoplasma of the tropical animals works more economically, especially at a higher temperature.

With the smaller animals examined by me I determined the change in the composition of the air of a space in which the sample-animal had found itself for a certain time. This time was chosen so as to make the air at last contain $3-4^o/_0$ CO_2. In this case the CO_2 quantity did not disturb the intensity of the respiration of the animal and the error in the experiment, arising from the analysis of the air, had been diminished [3]). The analysis of the air was made according to HEMPEL [4]). The CO_2 absorption took place with concentrated $NaOH_2$, the O_2 binding in a gas-pipette filled with phosphor (the temperature of the room was always above 15° C.). Bigger animals I put in a space through which the current of air was led. The air that entered was made free from CO_2, of the air that was going out the CO_2 was kept back in bottles by means of baryte-water, and the quantity was determined by titrating the remaining $Ba(OH)_2$.

In the different series of experiments I have brought together animals agreeing as much as possible in their bodily shape, and most of which belong to very closely related species. By this it seems to me that a comparison of the results is possible and the differences that show themselves are to be attributed to the difference

---

[1]) See ZUNTZ in HERMANN's Handbuch der Phys.
[2]) KREHL and SOETBEER, Pflügers Archiv. Bd. 77 p. 611—638.
[3]) For warmblooded animals, see Frédéricq in Diction. de Physiologie Vol. II. p. 449.
[4]) HEMPEL, Gasanalytische Methoden.

4

in size. That the origin of the animals from different hot climates is not of decisive influence, as KREHL and SOETBEER think, appears from the regular course of the numbers in the tables. Further, in connection with this, I draw attention to the fact that the Platyd. maur. (experiment II, Table I) of North Africa produces much more CO_2 p. hour and K.G. than the alligator species and the crocodile, which also originate from the torrid zone.

TABLE I

Temp. 18—19° C.	O_2 p. hour and K.G.	CO_2 p.hour and K.G.	Bodily weight
I Lacerta viridis var. maculosa (very movable)	—	551 cc	7.25 gr.
II Platydactylus mauritanica (in rest)	270 cc	171	8.055
III Molga torosa (in rest)	156	78	17 5
IV Salamandra maculosa (in rest)	128 7	99	28.32
V Alligator sclerops (in rest)	—	43	530.—
VI Alligator lucius (very movable)	—	90	797.—
VII Krokodillus porosus (moderately movable)	—	39	1467.—

It is seen that at an increase of the bodily weight the exchange of gas calculated per K.G. and hour, decreases. All the animals were full-grown and had been imprisoned for a long time at a temperature of ± 20° C., whilst the nutritive power was as good as possible. The diverging figures, which are found concerning the exchange of gas in frogs at an equal temperature and season, are for a great part to be attributed to the different nutritive power. Hence the importance of the following table, where all the animals had been fed as well as possible.

TABLE II

Temp. 18—19° C.	O_2 p. hour and K.G.	CO_2 p. hour and K.G.	Bodily Weight
I Pachytis Bombinator	325 cc	240 cc	5.88 gr.
II Hyla arborea	314	240	7.78
III Rana esculenta	210.9	152.7	30 —
IV „ „	80.7	58.3	116.—
V „ aspersa	—	45	563.—
VI Bubo marinus	—	22 1	1200.—

During the experiment all the animals moved as little as possible, so that the results are to be compared directly and once more show

the same result as the experiments in Table I. In these animals I could not trace the influence of motion on the exchange of gases. Uneasiness, however, betrays itself in the toads by the so-called blowing up (air-swallowing). A Bubo marinus in this state produced 60.7 $ccCO_2$ instead of 22.1 cc. CO_2 p. hour and K.G.

TABLE IIIa

	CO_2 p. K.G. and hour	Bodily Weight	Temp.
I Angius fragilis (moving)	473 cc	22 21	21° C.
II Amphysbaena alba (very movable)	168	373.4	20°

TABLE IIIb

III Coronella austriaca	292 cc	24.8	19° C.
IV Tropidonotis natrix	432	46.2	20°
V „ „	324	74.3	19°
VI Boa constrictor	52.5	810.—	19°
VII „ „	32	2830.—	19°

All the snakes and lizards had had no food that day, the ring-snakes (IV and V) had not eaten anything for some months past, the two Boas had had no food for a fortnight.

The influence of alimentation on the metabolism in the Boa constrictor is perceptible, but not so great as would be expected, which appears from the following table:

TABLE IV

		CO_2 p. hour and K.G.	Temp.
Boa constrictor 2830 Gr.			
a without food (see Table IIIb pr VII)		32	19° C.
b devoured a pigeon	after 4 hours	52.9	20.5°
c	52	49 4	20°
d	124	55.5	—
Boa constrictor 3123 Gr.			
a devoured 2 rats	after 2 hours	41.5	19°
b	24	42.5	19°
c	48	52.9	19°

4*

Thus far nearly all the experiments had been made upon full-grown animals; in the following experiments on the exchange of gases in tortoises a difference in bodily weight is accompanied by a difference in age.

TABLE Va

	CO_2 p.hour and K.G.	Bodily weight	Temp.
I Chelodina longicollis	53.3 cc	505 Gr.	19° C
II „ „	39	805	20°

TABLE Vb

	CO_2 p.hour and K.G.	Bodily weight	Temp.
III Chrysemus chineria (var. belli)	48.4	273	19°
IV „ „ „ (very movable)	50	1570	19°

TABLE Vc

	CO_2 p.hour and K.G.	Bodily weight	Temp.
V Testudo graeca	115	636	19°
VI „ tabulata	62	1099	20°
VII „ „	68	1650	23°

TABLE Vd

	CO_2 p.hour and K.G.	Bodily weight	Temp.
VIII Emys orbicularis	220	71	19°
IX „ „	74	135	19°
X „ „	33	589	19°
XI „ „	18	1190	19°

Besides the phenomenon already mentioned we may, from this table, also observe the influence of the growth upon the metabolism, the exchange of gases in the growing Emys orbicularis increasing more strongly with the fall of bodily weight than in full-grown animals.

In the Emys orbicularis an increase of bodily weight
in proportion of   1 : 17
gives a decrease in the production of CO_2 p. KG.
and hour of   12 : 1
In the snakes with an increase of   1 : 17.5
is found a decrease of CO_2 production p. KG. hour   8.3 : 1
in the amphibia of Table II an increase of   1 : 15
shows a decrease of CO_2 production per KG. hour   4 : 1
In the amphibia of Table I these figures are: increase   1 : 18.7
decrease of CO_2 production   2.3 : 1

It follows, therefore, from the experiments and investigations described here, which, moreover, have formerly been made upon warm-blooded animals by other investigators, that of similar or closely related animals the smaller ones have a relatively much stronger metabolism than the larger animals.

It seems to me that the explanation of this general phenomenon is not to be found in the influence of the size of the body on metabolism, as neither in the experiments mentioned here, nor in those formerly made upon sea-animals, anything of a proportion between exchange of gases and the size of the body (equalled to $K^{V}\overline{\text{weight}}$[2]) has appeared to me. Therefore it also seems to me that the theory, projected by von HOESSLIN [1]), should be put to the test by means of experiments. His supposition that metabolism of cold-blooded animals, just as that of warm-blooded, is proportional to their size, does not seem to be corroborated by experiments.

Further the writer thinks, that the alimentary matter with which the blood supplies the textures in the different animals, is proportional to the size of the animals; at which of the many moments at least a few have been left out of consideration.

Besides, in the animal organism the degree of the supply of food for the textures is determined by the degree of metabolism, and not the reverse: metabolism by the circulating quantity of blood. Moreover the influence of the movements of smaller and larger animals on their metabolism cannot be calculated without any investigation.

It may, however, be concluded that the law of dependence of consumption of oxygen on the size of warm-blooded animals, as has so irrefutably been proved by RUBNER [2]) for dogs, finds its origin in the general vital phenomenon mentioned here. According to this principle the regulation of the temperature in the smaller warm-blooded animals does not take place by a relatively decreased giving off of warmth (thicker skin- or skin-covering, narrower vessels, etc.), but by a relatively stronger production of warmth.

Utrecht, 25 April.

---

[1]) v. HOESSLIN, Archiv. f. (Anat. u.) Physiol 1888 p. 323—380.

[2]) RUBNER Zeitschr. f. Biolog. Bd. 19.