

XXII. *On the respiration of birds.* By WILLIAM ALLEN and WILLIAM HASLEDINE PEPYS, *Esqrs. Fellows of the Royal Society.*

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OUR communications to the Royal Society, as printed in the *Phil. Trans.* for 1808 and 1809, detailed the effects produced when the human subject or a guinea-pig respired, either atmospheric air alone, or pure oxygen, or a mixture of hydrogen and oxygen. We thought it would render the subject more complete if we extended our inquiries to the respiration of birds, and accordingly made several experiments with pigeons in the same apparatus that we employed for the guinea-pig. The apparatus is engraved and described in the *Phil. Trans.* for 1809, page 429.

First experiment with atmospheric air.

A pigeon was placed in the intermediate glass vessel, in 62 inches of air on the mahogany stand over quicksilver, between the two gasometers communicating with the vessel in which the pigeon was confined. One of the gasometers was empty, but connected by tubes and stop cocks with the quicksilver bath, and also with the intermediate vessel; the other contained the air for the supply of the pigeon. The barom. being 30.130, the therm. 54° , during 69 minutes, at intervals of four or five minutes, 35 cubic inches at a time of common air were slowly passed through the vessel in which the bird was confined; the other gasometer of course received what was pushed off, the quantity was noticed by its register, and a portion was received by a bottle in the quicksilver bath for examination; in this way 525 cubic inches of common air were supplied, to which the 62 cubic inches in the intermediate glass vessel being added, made a total of 587 cubic inches in which the pigeon had respired for 69 minutes. The registers of both gasometers agreed throughout to a very trifle, which confirmed our former observations, that there is no change in the volume of atmospheric air when respired under natural circumstances.

At the end of the first twelve minutes we noticed a good deal of dew upon the glass opposite to the head of the pigeon ; at first we gave a fresh supply of air every five minutes, but at the end of 31 minutes the bird appearing a little uneasy, we supplied him every four minutes ; and at the close of the experiment, which lasted 69 minutes, he did not appear the worse for it. We thought that the register indicated a slight diminution of volume during the time that the bird was uneasy ; the air respired was examined as usual, with lime water in the eudiometer with an elastic bottle, for carbonic acid, and with green sulphate of iron saturated with nitrous gas, for oxygen.

State of the air before the experiment : Atmospheric air 587 cubic inches, consisting of 123 oxygen, 464 azote.

State of the air after the experiment : 587 cubic inches, consisting of 35.80 carb. acid, 87.52 oxyg., 462.67 azote. $35.80 \div 69 = .52$ cubic inches per minute. Thus it appears that the bird produced about half a cubic inch of carbonic acid per minute ; and as the volume of oxygen consumed is always equal to the volume of carbonic acid produced, the 35.80 being added to the oxygen found after the experiment, or 87.52 cubic inches, very nearly corresponds with the 123 contained in the common air before the experiment. Now as 100 cubic inches of carbonic acid contains 12.82 grains of carbon, the 35.80 cubic inches produced by the bird in 69 minutes must contain 4.59 grains of carbon, or nearly at the rate of 96 grains in 24 hours.

The azote before the experiment was 464 cubic inches ; after the experiment 462.67 : the difference is only 1.33, or little more than a cubic inch, which loss might have happened during the time the bird was uneasy ; and we may fairly conclude that when birds respire atmospheric air, the only change in the air is, the conversion of a part of its oxygen into a corresponding portion of carbonic acid gas.

First experiment with oxygen gas.

The oxygen was made from chlorate of potash, and being examined as usual with the eudiometer, it was found to contain 2 per cent of azote.

The barom. being 29.5, the therm. 51° , we placed the pigeon in the intermediate glass vessel in the same situation as in the former experiment.

The capacity of the glass vessel was	94 cubic inches.
Connecting tubes, &c.	5
	99
Bulk of bird	28
Atmospheric air	71

Thus it appears that 71 cubic inches of atmospheric air were contained in the glass vessel with the pigeon, and during 22 minutes 75 cubic inches of oxygen gas were passed through this vessel at intervals of about 7 minutes, the quantity pushed off being noticed by the register of the second gasometer.

In about ten minutes the bird began to pant and became uneasy; during the next 21 minutes 72 cubic inches more of oxygen gas were passed: the bird continued to pant, and the soft parts about his beak became of a bright red.

In the next 23 minutes 89 cubic inches more of oxygen were passed, and the bird was left 6 minutes longer in the 71 cubic inches contained with him in the intermediate glass vessel, making the whole time one hour and twelve minutes; the bird on being released appeared very well, and did not seem at all injured by the experiment. The gas being examined by the eudiometer as before, the following results were obtained:

Vol. of gas before the expt. cub. inch.		Azote.	Oxygen.	Time.	Vol. of gas after expt.		Azote.	Oxygen.	Carbonic Acid.
71	atmos. air consisting of	56.69	14.31						
75	oxyg. with 2 per cent azote	1.50	73.50	22'	75	consisting of	48.22	22.96	3.82
72	oxyg. ditto	1.44	70.56	21	71.99	. . . . .	23.75	43.79	4.45
89	oxyg. ditto	1.78	87.22	23	89	. . . . .	10.90	70.90	7.20
				Residuum 6	71	. . . . .	7.24	57.96	5.80
<u>307</u>		<u>61.41</u>	<u>245.59</u>	<u>72</u>	<u>306.99</u>		<u>90.11</u>	<u>195.61</u>	<u>21.27</u>

Thus it appears that the volume of the gas was almost unaltered, but that there had been a great disturbance in the proportions of the azote.

Azote in the 307 cubic inches of gas:

Before the experiment	61.41
Found after the experiment	90.11
Increase of azote	28.70

Oxygen in the 307 cubic inches of gas :

Before the experiment	245.59
Found after experiment	195.61
In carbonic acid gas	21.27
	216.88
Loss of oxygen	28.71

This agrees with the facts stated in our former paper in the experiment with the guinea-pig ; but there is a striking difference in the case of the carbonic acid ; so far from there being an increase of it when the pigeon breathed oxygen, there was a considerable diminution. $21.27 \div 72' = .29$ of a cubic inch per minute, which is little more than a quarter of a cubic inch per minute ; but he produced more than half a cubic inch in the same time when he breathed common air ; and with regard to the increase of the azote, we may remark that at the end of the first period of 22 minutes, rather less than ten cubic inches of azote were left, for

$$\left. \begin{array}{l} 56.69 + 1.50 = 58.19 \text{ azote before} \\ \text{and} \quad \quad \quad 48.22 \text{ azote after} \end{array} \right\} = 9.97 \text{ of the original azote left.}$$

In the following period of 21 minutes none of the original azote was left, but there was an increase of about 13 cubic inches. In the next period of 23 minutes only 1.44 of azote was admitted, but 10.90 were found ; thus $10.90 - 1.44 = 9.46$ of azote evolved in that time ; it seems therefore plain that oxygen must have been absolved by the blood in the lungs, and a corresponding volume of azote given out.

Second experiment with oxygen gas.

The oxygen gas was made as before from chlorate of potash, and contained in this instance only one per cent of azote.

Barom. 30.50, therm. 45°. The quantity of atmospheric air with the pigeon in the intermediate vessel was 69 cubic inches ; during the first 20 minutes 62 cubic inches of oxygen were supplied. In about a quarter of an hour he began to open his beak, pant, shake his head and appear uneasy, frequently drawing the film over his eyes, and often putting out his tongue, the respiration becoming quicker. When he had been in about 40 minutes his beak reddened

very much, and he opened it every time he breathed; there was more moisture on the glass opposite to his head, than in the experiment with common air. Towards the conclusion of the experiment, which lasted one hour and ten minutes, the film was pretty constantly over his eyes, but on being taken out he was quickly as well as usual.

The following was the state of the gas before and after the experiment:

Vol. of gas before the expt. cub. inch.		Azote.	Oxygen.	Time.	Vol of gas after expt.	Azote.	Oxygen.	Carbonic Acid.
69 atmos. air	=	54.51	14.49					
62 oxyg. 1 per cent	=	.62	61.38	20'	76.5	= 42.33	29.90	4.27
86 oxyg.	=	.86	85.14	21	75	= 19.80	48.73	6.47
84 oxyg.	=	.84	83.16	29	73.5	= 8.56	58.43	6.51
					7	= .71	5.60	.69
					Residuum 69	= 7.	55.20	6.80
301		56.83	244.17	70	301.0	78.40	197.86	24.74

Here again the volume of gas appears to be unaltered: the production of carbonic acid gas is but little more than in the last experiment,

$$24.74 \div 72 = .35 \text{ cubic inch per minute;}$$

but the proportions of azote are altered as in the former experiment: thus

Azote in the 301 cubic inches of gas.

Before the experiment	56.83
Found after the experiment	78.40
	21.57

Oxygen in the 301 cubic inches of gas.

Before the experiment	244.17
Found after the experiment	197.86
In carbonic acid gas	24.74
	222.60
	21.57

It is interesting to notice here also the state of the azote at different periods of the experiment.

In the first period of 20 minutes the azote before respiration was

	$54.51 + 62 = 55.13$
Azote found	42.33
	<hr style="width: 50px; margin-left: auto;"/>
Azote left	<u>12.80</u>

Second period of 21 minutes.

	$12.80 + 86 = 13.66$
Azote found	19.80
	<hr style="width: 50px; margin-left: auto;"/>
Increase of azote	<u>6.14</u>

Third period of 29 minutes.

Azote in 84 cubic inches of oxygen . . .	.84
Found	$8.56 + .71 + 7 = 16.27$
	<hr style="width: 50px; margin-left: auto;"/>
Increase of azote	<u>15.43</u>

$15.43 + 6.14 = 21.57$ total increase of azote. Here the loss of oxygen exactly equals the increase of azote.

Mixture of hydrogen and oxygen.

We next tried the effects of an artificial atmosphere, substituting hydrogen for azote; the oxygen made as before contained 3 per cent of azote, and detonating 10 parts of it with 20 of hydrogen in VOLTA's eudiometer, the whole volume of gas disappeared except about one part which was azote, and this confirmed the result with the other eudiometer and green sulphate of iron saturated with nitrous gas.

There were but 64 cubic inches of common air this time in the intermediate vessel containing the pigeon at the beginning of the experiment, and 187 cubic inches of a mixture of hydrogen and oxygen, in which the oxygen was in about the same proportion to the hydrogen as it is to the azote in the common air, were gradually passed through the intermediate vessel during 26 minutes.

Duration of
the expt.

at 55' after 2 P.M. the pigeon was put into the vessel with common air; moisture almost immediately began to condense on the inside of the glass.

Duration of the expt.

6' at 1' after 3 P.M. made 35 cubic inches of the mixture pass slowly through the vessel.

10 at 5 after 3 P.M. passed 35 cubic inches more; the bird became uneasy.

15 at 10 after 3 P.M. passed 35 cubic inches more.

18 at 13 after 3 P.M. the bird now panted very much, but was relieved as soon as more of the mixture was admitted, passed 35 cubic inches.

22 at 17 after 3 P.M. passed 35 cubic inches more.

23 at 18 after 3 P.M. passed 12 inches; being the last the bird struggled.

26 at 21 after 3 P.M. took it out, but it did not seem to be in the least injured.

The following was the state of the gas before and after the experiment:

Vol. of gas before the expt. cub. inch.	Azote.	Oxygen.	Hydrog.	Time.	Vol. of gas after expt.	Azote.	Oxygen.	Carbonic Acid.	Hydrog.
64.00 atmos. air	= 50.56	13.44							
39.27 oxygen 3 per cent =	1.18	38.09							
147.73 hydrogen			147.73	26'	250.99	86.97	34.15	17.62	112.25
	51.74	51.53							
<u>251.00</u>									

Azote in the 251 cubic inches of gas.

Before the experiment 51.74

Found after the experiment 86.97

Increase of azote 35.23

Oxygen in the 251 cubic inches of gas.

Before the experiment 51.53

Found after the experiment 34.15

In carbonic acid 17.62

51.77

The volume nearly the same after as before the experiment.

Hydrogen in the 251 cubic inches of gas.

Before the experiment 147.73

Found after the experiment 112.25

Loss of hydrogen 35.48

17.62 ÷ 26' = .68 cubic inches per minute.

The production of carbonic acid in this case was somewhat greater than in atmospheric air ; but the remarkable feature of this experiment is, that, except in the formation of carbonic acid, the oxygen remains nearly unchanged, while the whole loss falls upon the hydrogen ; so that the blood appears to have absorbed a quantity of hydrogen, and given out a proportionate quantity of azote, the total volume of gas before and after the experiment remaining nearly the same.

The present experiments tend to strengthen and confirm our former conclusions, and prove that when atmospheric air alone is respired in a natural way, the proportion of azote is not altered, and that there is only a change of a certain portion of oxygen for an equal portion of carbonic acid gas ; that when a larger proportion of oxygen than is contained in atmospheric air is respired, a quantity of oxygen is absorbed by the blood, and an equal quantity of azote gas evolved.

That when a mixture of hydrogen, oxygen, and azote are respired, the oxygen being in the same proportion as in atmospheric air, there is no loss of oxygen, but a quantity of hydrogen disappears and is replaced by the same quantity of azote.

The circulation of the blood is quicker in birds than in other animals ; and if we may judge from the effects produced upon the pigeon, they are more sensible to the stimulus of oxygen.