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SOME FURTHER OBSERVATIONS ON HEAT-DYSPNŒA.

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In an article published in Vol. II., No. 3, of this Journal, on so-called heat-dyspnœa, I showed that the increase in the number of respirations which an animal presents when exposed to a warm atmosphere, and while its temperature went up, was principally due to peripheral influences; but I further stated that the heated blood might also act directly on the centres in the medulla, though, if so, producing less effect than the peripheral stimuli.

In the following short communication, I propose to give further support to the first statement, and discuss the second as well as another which I touched in the published essay, namely, the action on the medulla of higher temperatures than those used in my former investigations.

I feel the more inclined to add further proofs to support the conclusions which I reached, as views contradictory to them and based on Goldstein's experiments, which I have shown to be imperfect and inconclusive, are taught in several text books of Physiology, and are gaining ground in the medical profession.

Foster says, on page 377, 3rd Edition: "If the blood in the carotid artery in an animal be warmed above the normal, dyspnœa is at once produced. The over-warm blood hurries on the activity

of the nerve cells of the respiratory centre, so that the normal supply is insufficient for their needs. The condition of the blood then affects respiration by acting directly on the respiratory centre itself."

Fick says, on page 266 of his Physiology, 2nd Edition: "If an animal is artificially heated several degrees above its normal temperature, the respirations become deeper and very much more frequent, even if the quality of the blood is in nowise changed; yes, even when by energetic artificial inflations arterialisation of the blood is insured; indeed, it is quite impossible in an animal thus super-heated to produce the state of apnœa. That reflex influences do not come into play here—*e.g.*, from the heated skin—can easily be proven by the following experiment. By application of the proper apparatus one can succeed in heating nothing but the blood flowing in the carotid arteries. As soon as that takes place the frequency of the respirations rises just in the same way as if the whole animal had been heated. From that one must conclude, that it is the increase of the temperature in the respiratory centre itself which increases the irritability, and at the same time diminishes the resistance, so that the exciting agent produces in the same unit of time deeper and more frequent respirations."

In an article on Progressive Pernicious Anæmia, by Herbert Jones, published in the *Practitioner*, February, 1880, we read this: "Heat is also a stimulant to the respiratory centre in the medulla oblongata, by which the movements of respiration are regulated, and as Fick and Goldstein have shown, when warm blood is supplied to this centre the respiratory movements become quicker and deeper until marked dyspnœa takes place, although the blood which is circulating in the rest of the body still retains its normal temperature."

I let Exp. 1, see Table I., precede the remarks which I wish next to make. The observation it records, like the rest of my experiments, was carried out on a dog. The temperatures, during my observation, were taken in the rectum or vagina.

I had various reasons for undertaking this experiment. In the former investigation I had found that one animal might breathe 200 to 300 times a minute without its temperature going up, and *vice versâ*, the temperature of another animal might go up several degrees while the respirations went up from 26 to 62 per minute only, the cord in the latter being divided in the lower cervical region.

Table I.

No. of observation.	Time.	Temp. to which animal is exposed.	Temperature of animal.	Respirations per minute.	
					WEDNESDAY.
1	10.05	24	38·9	28	Tracheotomized.
2	40	41			Head only in apparatus, breathing warm air through tube.
3	48	44	38·9	86	
4	53	42	38·9	120	
5	58	44	38·9	132	
6	11.05	44	39	200	
7	10	46	39	204	
8	17	48	39	268	
9	20	48	39·1	280	Panting.
10	29	49	39·1	280	
11	35		39·1		Artificial respiration for 2 minutes with cool air, apnœa for ¼ minute ; shallow respiration for 1 minute ; out of apparatus.
12	40	50			
13	45				Artif. resp. for 2 min. ; no apnœa.
14	55		39·1	216	
15	12.30		38·9	37	
16	42		38 9	30	
17	44				Artificial respiration ; apnœa of 1½ minute.
18	1.00		39	36	
19	1.01				Placed in apparatus ; head free.
20	06	35	39	152	
21	11	37	39	240	
22	15	38	39		Artif. respiration for 2 minutes ; no apnœa.
23	20	37	39·1	228	
24	25	38	39·2	310	Panting.
25	30		39·3		Artif. respiration for 2 minutes ; no apnœa.
26	31				Taken out of apparatus.
27	34		39·3	280	
28	3.15				Cord cut.
29	4.27	50	37·6	18	Placed in apparatus ; head and arms free.
30	5.10	58	37·8	18	
31	25	49	38	20	
32	30				Artif. respiration ; apnœa of over 1 minute.
33	47	60	38·5	18	
34	57	60	38·9	22	
35	6.21		39·5	24	

No. of observation.	Time.	Temp. to which animal is exposed.	Temperature of animal.	Respirations per minute.	
					WEDNESDAY.
36	6.23	60	39·5		Artificial respiration ; apnœa of ¾ minute.
37	36	60	39·7	24	
38	46	60	40	21	
39	58		40·1		Artif. resp. for 2 min. ; apnœa over 1 min.
					THURSDAY.
40	9.20		37		Artif. resp. of 2 min. ; apnœa of 1½ min.
41	25	60	37	19	Placed in apparatus.
42	10.30	63	40·8	26	
43	35				Artificial respiration ; apnœa of ½ minute.
44	38	55	41·4	40	
45	43				Artificial respiration ; apnœa of ½ minute.
46	47	50	42	100	Begins to pant.
47	50	49	42·5	156	
48	55	49	42·5		Artificial respiration ; no apnœe.

These facts being brought out on different animals, one object here was to try one and the same animal. That is, to take account of increased temperature, if there was any, and increased number of respirations before the cord was cut and after the cord was cut in the same dog. It will be seen that the present results agree with the former conclusions. The same dog is made to breathe 240 times a minute (Obs. 21) while having a temperature of 39 (38·9 had been the temperature of the dog when the experiment began). When we look, however, for the respiratory rate at the temperature of 39, after the dog's cord had been divided, we find it (Obs. 34) 22. And if the objection were to be made that the dog was unable to breathe rapidly on account of the section of the cord, by looking towards the

end of the table it will be found that this is not the reason, for the dog can make as many as 156 respirations in a minute.

We see, then, that in the same dog, when exposed to warm air acting on a large surface, connected by afferent nerve paths with the medulla, the respirations may go up enormously without the animal's temperature rising; and, on the other hand, the respirations may go up less than 25 per cent., while the temperature increases over one degree Celsius; in this latter case the greater part of the skin being thrown out of nervous connection with the medulla by previous section of the cord.

It will further be observed, by glancing over the table, that artificial respiration was carried on several times. Some of these produced apnœa, others did not. At 12.44 (Obs. 17), while the animal was at 38·9°, and not in the warming apparatus, apnœa of 1½ min. was produced. At 1.15 (Obs. 22), while the animal was at 39°, *i.e.*, only 0·1° higher than before (practically not higher at all), the same amount of inflation was not successful. That the 0·1° of temperature was not the cause for this condition is shown further on. When the cord had been cut apnœa was successfully produced, although the temperature of the animal had risen not 0·1°, but 1·1°. Again, when finally (Obs. 47) the temperature had reached 42·5, and the respirations 156, the efforts at producing apnœa were again fruitless. It is clear from this that it is not the temperature of the blood *per se* which makes apnœa impossible. We see apnœa may be possible both at normal and at elevated temperatures; it may also be impossible both at normal and at elevated temperatures; the reason of the difference being that the dog cannot be made apnœic if he pants vigorously. Of course there is a limit when artificial respiration will at times be successful and at times not: just when the respiration *begins* to grow rapid and take on the character of panting, as is shown in Table II., when the dog had the head only in the apparatus. Here, then, we have another support for our conclusions. In the last paper it was shown that it was not the heat acting on the centres which produces this condition of the animal, in which it cannot be made apnœic. The present observations show the other side of the same fact, and make it evident that peripheral influences, due to exposure of the skin only, may be so strong that they do not allow the centre to come to rest, although there is no venosity of the blood to act as a stimulus, nor has the animal's temperature risen more than a degree.

In the third place, it will be seen (Obs. 46—48, Table I.), that the dog did commence to pant—with the cord cut—after he had reached a temperature of 42.

Let me recall now one of the conclusions of my previously-published paper: "The increased respirations . . . . are due to two causes, skin stimulation and warmed blood." A somewhat closer consideration makes it evident that the experiments there given were not sufficient to show that the warmed blood has any direct central effect: for although by section of the cord in the lower cervical region a large part of the skin was thrown out, yet the fore limbs, neck, and sensitive head, mouth, and tongue remained in connection with the medulla; and although in the experiment the direct action of the heated air from without was prevented by keeping the animal's head, &c., out of the warm chest, yet this did not preclude the heating of the nerves of the skin of those parts from within by means of the blood which had been heated in the other parts of the body flowing into them.

To show how sensitive the mucous membrane of the mouth and the tongue is, I add Exp. 2, Table II.

Table II.

December 3rd, 1879.

No. of observation.	Time.	Temp. in apparatus.	Temp. of animal.	Rate of respiration.	
1	7.53	42	39	26	
2	55				Head and fore-feet placed in apparatus.
3	8.01	40	38·9	40	
4	06	40	39	52	
5	08	40	39·1	90	
6	09	40	39·1	152	
7	12	40	39·1	66	Nose free.
8	15	39	39	92	Nose back in oven.
9	16	40	39·1	160	
10	18	40	39·1		Dog pants.

In this experiment it was the aim to have the surrounding air which the animal took into its mouth not very hot, not warmer than the blood was when the dog began to pant in the experiment above referred to. The experiment shows that exposure of a small part of the body, mouth, neck, and fore limbs, to this not very high temperature is sufficient to

produce quickened breathing and even panting, although the animal's temperature is not raised. Human experience agrees with this; if in the effort of getting into perspiration by means of a hot-air bath one keeps the head under the sheet and thus breathes air of about the body temperature one finds the respirations similarly increase in frequency.

In the former paper it was shown, that the temperatures there employed (41·3) did not produce the panting when the cord had been cut, and it was left for further investigation whether higher blood temperatures might produce such an effect by action on the centres directly. The setting in of panting in Exp. 1 when the dog had reached the temperature of over 42 might be adduced to support the view, that the heat in conditions like the above acts centrally, the cord having been cut. But the foregoing remarks show that such a conclusion would not be justified, as the peripheral influences from mouth and head are not excluded; nor were those from the lung nerves. I cannot see how to throw out these peripheral influences altogether, and the question, possibly, must remain an open one, although there cannot be adduced any fact showing a direct action of heat on the centres.

A third experiment, see Table III., however, was devised in which peripheral influences were eliminated as much as possible.

Table III.

January 9, 1880.

No. of observation.	Time.	Temp. in apparatus.	Temp. of animal.	Rate of respiration.	
1	10.30		36·7		Cord and pneumogastrics are cut.
2	11.40	14	32	7	
3	12.43	13	30	6	
4	12.52	40	30	6	Placed in apparatus; head and fore limbs free.
5	1.35	57	31	6	
6	2.53	50	34	9	
7	3.03	50.	36	9	
8	3.10	53	37	10	
9	3.24	60	38	10	Ice in cloths placed around head.
10	3.29	60	38·5	9	

No. of observation.	Time.	Temp. in apparatus.	Temp. of animal.	Rate of respiration.	
11	3.45	65	38·9	10	
12	4.14	67	40	8	
13	17	67	40·5	10	
14	24	63	41	13	
15	30	60	41·3	12	Artificial respiration necessary.
16	31				Respiration shallow and weak.
17	33	59			Artificial respiration necessary.
18	34		41·4	12	Artificial respiration necessary.
19	36	59			Respirations shallow.
20	40		41·7	12	Muscles twitching.
21	45			18	
22	49	58	42	20	Efforts at respirations rather than respirations.
23	50		42	16	
24	55		42		Artificial respiration.
25	57	58	42		Dog died.

Table III. then shows that when cord and pneumogastrics are cut the increase in the number of respirations is very low indeed. This certainly does not look as if the hot blood had the power to directly diminish resistance and increase the irritability of the respiratory centre. It is not without interest to observe how the panting can be produced if the cord is cut and the pneumogastrics preserved—in that case, however, the temperature must be raised considerably—and how it can likewise be produced when the pneumogastrics are cut and the cord left intact, in that case the temperature need hardly be raised at all. But when both cord and pneumogastrics are cut panting is not seen, excepting under certain artificial conditions.

The next question, then, would be how much is due to the peripheral stimulation of the vagus-endings in the lungs by the increased temperature, and do they act just like the nerves of the skin? Are they sensitive to warmth?

Exp. 4, Table IV., may help to answer this question.

Table IV.

March 4th, 1880.

No. of observation.	Time.	Temp. in apparatus.	Temp. of animal.	Rate of respiration.	
1	7.35		39·2	36	The temp. in this exp. from No. 9 onwards refers to the heated air in the can. The evening was very warm and close.
2	45		39·2	45	
3	55	34	39·1	70	
4	8.00		39·2	184	
5	15				Cord cut.
6	23		38·8	50	
7	28		38·8	47	
8	40		38·5	38	Dog's trachea-tube connected with a large tin containing water at elevated temp. and Ba. $(O.H.)_2$.
9	55	48	38·4	36	
10	9.05	50	38·4	32	
11	23	53	38·3	29	
12	38	53	38·3	28	
13	43				Placed in warm apparatus.
14	10.06	59	38·8	32	
15	12	61	39·2	52	
16	15	58	39·5	60	
17	20	60	39·9	90	
18	25		40·4	160	
19	28	60	40·5	176	Pneumogastrics cut.
20	32	60	40·9	232	
					March 5th.
21	8.40		34·5	21	
22	45	41			Placed in apparatus.
23	9.08	52	35	16	
24	37	63	37	14	
25	48	54	38	18	
26	10.01	55	39·2	19	
27	06	49	40	20	
28	20	50	41	8	
29	30	51	41	14	
30	40	50	41·8	10	
31	48	50	42	44	Artificial respirations for two minutes.
32	55	50	42·5	52	
33	11.00	51	42·6	52	
34	05	52	43·2	36	
35	15		43·6	156	

We can gather, then, from Table IV. that giving the animal warm and moist air to breathe did not seem to have any effect on the peripheral vagus fibres, the animal was not made to pant thus; and, again, cutting the nerves did not stop the panting after it had once been set up. The same observation was made on a dog in which the cord was intact, the animal breathing hot air. The respirations were not permanently diminished by cutting the vagi.

But why did the dog not pant the next day after reaching a temperature of 41? Or why not in Table III.?

I may add here that the dog would not have reached before dying the high temperatures which it did in Table IV. if artificial respiration had not assisted him; and, further, the observation has repeatedly been made, that the respirations go up in frequency during artificial respiration and remains high a little time afterwards.

Regarding the depth of the respirations, I cannot support the statement that they grow deeper. Tracings which I have taken show that they grow more shallow, as it also appears to ordinary observation. Accidentally I found out, I think, how Fick's statements, that they grow deeper, came to be made. In an experiment which I made the board on which the dog rested got a little too hot accidentally, and then the respiratory movements grew deeper. As soon as the animal was protected from pain they went back to their normal character, showing more limited excursions than the respiration at the normal temperature.