

XII. *Experiments and Observations in an heated Room*

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Redde, Feb. 16,
1774. ABOUT the middle of January, several gentlemen and myself received an invitation from Dr. GEORGE FORDYCE, to observe the effects of air heated to a much higher degree than it was formerly thought any living creature could bear. We all rejoiced at the opportunity of being convinced, by our own experience, of the wonderful power with which the animal body is endued, of resisting an heat vastly greater than its own temperature; and our curiosity was not a little excited to observe the circumstances attending this remarkable power. We knew, indeed, that of late several convincing arguments had been adduced, and observations made, to shew the error of the common opinions on this subject; and that Dr. FORDYCE had himself proved the mistake of Dr. BOERHAAVE^(a) and most other authors, by supporting many times very high degrees of heat, in the course of a long train of important experiments; with which, and his most philosophical conclusions from them, every lover of science must earnestly wish that he may soon favour the public. In the mean time time, I am happy in an opportunity of laying before this So-

(a) *Elem. Chæmiæ*, tom. I. p. 277, 278.

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ciety the following short account of some of these experiments, and of the views with which they were undertaken; for the particulars of which I am obliged to Dr. FORDYCE himself.

DR. CULLEN long ago suggested many arguments to shew, that life itself had a power of generating heat, independent of any common chemical or mechanical means; for, before his time, the received opinions were, that the heat of animals arose either from friction or fermentation^(b). Governor ELLIS in the year 1758 observed^(c), that a man can live in air of a greater heat than that of his body; and that the body, in this situation, continues its own cold. The Abbé CHAPPE D'AUTEROCHE informs us, that the Russians use their baths heated to 60°^(d) of REAUMUR's thermometer, about 160 of FAHRENHEIT's, without taking notice, however, of the heat of their bodies when bathing. With a view to add further evidence to these extraordinary facts, and to ascertain the real effects of such great degrees of heat on

(b) To do further justice to the philosophy of this most ingenious and respectable professor, I must here declare, that during my stay in Edinburgh, from the year 1765 to 1769, the idea of a power in animals of *generating cold* (that was the expression) when the heat of the atmosphere exceeded the proper temperature of their bodies, was pretty generally received among the students of physic, from Dr. CULLEN's arguments; in consequence of which I applied a thermometer, in a hot summer-day, to the belly of a frog, and found the quicksilver sink several degrees: a rude experiment indeed, but serving to confirm the general fact, that the living body possesses a power of resisting the communication of heat.

(c) Philosophical Transactions, vol. L. p. 755.

(d) Voy. en Siberie, tom. I. p. 51.

the human body, Dr. FORDYCE tried the following experiments.

He procured a *suite* of rooms, of which the hottest was heated by flues in the floor, and by pouring upon it boiling water; and the second was heated by the same flues, which passed through its floor to the third. The first room was nearly circular, about ten or twelve feet in diameter and height, and covered with a dome, in the top of which was a small window. The second and third rooms were square, and both furnished with a sky-light. There was no chimney in these rooms, nor any vent for the air, excepting through crevices at the door. In the first room were placed three thermometers; one in the hottest part of it, another in the coolest part, and a third on the table, to be used occasionally in the course of the experiment: the frame of this last was made to turn back by a joint, so as to leave the ball and about two inches of the stem quite bare, that it might be more conveniently applied for ascertaining the heat of the body, and several other purposes.

EXPERIMENT I.

In the first room the highest thermometer stood at 120° , the lowest at 110° ; in the second room the heat was from 90° to 85° ; the third room felt moderately warm, while the external air was below the freezing point. About three hours after breakfast, Dr. FORDYCE having taken off all his cloaths, except his shirt, in the third room, and being furnished with wooden shoes, or rather sandals tied on with lilt, entered into the second room, and staid five minutes

minutes in a heat of 90° , when he began to sweat gently. He then entered the first room, and stood in the part heated to 110° ; in about half a minute his shirt became so wet that he was obliged to throw it aside, and then the water poured down in streams over his whole body. Having remained ten minutes in this heat of 110° , he removed to the part of the room heated to 120° ; and after staying there twenty minutes, he found that the thermometer placed under his tongue, and held in his hand, stood just at 100° , and that his urine was of the same temperature. His pulse had gradually risen till it made 145 pulsations in a minute. The external circulation was greatly increased; the veins had become very large, and an universal redness had diffused itself over the body, attended with a strong feeling of heat. His respiration, however, was but little affected. Here Dr. FORDYCE remarks, that the moisture of his skin most probably proceeded chiefly from the condensation of the vapour in the room upon his body. He concluded this experiment in the second room, by plunging into water heated to 100° ; and, after having been wiped dry, was carried home in a chair; but the circulation did not subside for two hours, after which he walked out in the open air, and scarcely felt the cold.

EXPERIMENT II.

In the first room the highest thermometer varied from 132° to 130° ; the lowest stood at 119° . Dr. FORDYCE having undressed in an adjoining cold chamber, went into the heat of 119° ; in half a minute the water poured down in streams over his whole body, so as to keep that part of the
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floor where he stood constantly wet. Having remained here fifteen minutes, he went into the heat of 130° ; at this time the heat of his body was 100° , and his pulse beat 126 times in a minute. While Dr. FORDYCE stood in this situation, a Florence flask was brought in, by his order, filled with water heated to 100° , and a dry cloth, with which he wiped the surface of the flask quite dry; but it immediately became wet again, and streams of water poured down its sides; which continued till the heat of the water within had risen to 122° , when Dr. FORDYCE went out of the room, after having remained fifteen minutes in an heat of 130° ; just before he left the room his pulse made 139 beats in a minute, but the heat under his tongue, in his hand, and of his urine, did not exceed 100° . Here Dr. FORDYCE observes, that as there was no evaporation, but constantly a condensation of vapour on his body, no cold was generated but by the animal powers. At the conclusion of this experiment, Dr. FORDYCE went into a room where the thermometer stood at 43° , dressed himself there, and immediately went out into the cold air, without feeling the least inconvenience; on which he remarks, that the transition from very great heat to cold is not so hurtful as might be expected, because the external circulation is so excited, as not to be readily overcome by the cold. Dr. FORDYCE has since had occasion, in making other experiments, to go frequently into a much greater heat, where the air was dry, and to stay there a much longer time, without being affected nearly so much, for which he assigns two reasons;

that dry air does not communicate its heat like air saturated with moisture; and that the evaporation from the body, which takes place when the air is dry, assists its living powers in producing cold. It must be immediately perceived, that, besides the principal object, these curious experiments throw great light on many other very important subjects of natural philosophy.

January 23. The honourable Captain PHIPPS, Mr. BANKS, Dr. SOLANDER, and myself, attended Dr. FORDYCE to the heated chamber, which had served for many of his experiments with dry air. We went in without taking off any of our cloaths. It was an oblong-square room, fourteen feet by twelve in length and width, and eleven in height, heated by a round stove, or *cockle*, of cast iron, which stood in the middle, with a tube for the smoke carried from it through one of the side walls. When we first entered the room, about 2 o'clock in the afternoon, the quicksilver in a thermometer which had been suspended there stood above the 150th degree. By placing several thermometers in different parts of the room we afterwards found, that the heat was a little greater in some places than in others; but that the whole difference never exceeded 20°. We continued in the room above 20 minutes, in which time the heat had risen about 12°, chiefly during the first part of our stay. Within an hour afterwards we went into this room again, without feeling any material difference, though the heat was considerably increased. Upon entering the room a third time, between five and six o'clock after dinner, we observed

served the quicksilver in our only remaining thermometer at 198° ^(c): this great heat had so warped the ivory frames of our other thermometers that every one of them was broken. We now staid in the room, all together, about 10 minutes; but finding that the thermometer sunk very fast, it was agreed, that for the future only one person should go in at a time, and orders were given to raise the fire as much as possible. Soon afterwards Dr. SOLANDER entered the room alone, and saw the thermometer at 210° ; but, during three minutes that he staid there, it sunk to 196° . Another time, he found it almost five minutes before the heat was lessened from 210° to 196° . Mr. BANKS closed the whole, by going in when the thermometer stood above 211° ; he remained seven minutes, in which time the quicksilver had sunk to 198° ; but cold air had been let into the room, by a person who went in and came out again during Mr. BANKS's stay. The air heated to these high degrees felt unpleasantly hot, but was very bearable. Our most uneasy feeling was a sense of scorching on the face and legs; our legs particularly suffered very much, by being exposed more fully than any other part to the body of the stove, heated red-hot by the fire within. Our respiration was not at all affected; it became neither quick nor laborious; the only difference was a want of that refreshing sensation which accompanies a full inspiration of cool air. Our time was so taken up with other observations that we did not

(c) This thermometer stands, near the boiling point, about a degree too high; the scale is FAHRENHEIT's.

count our pulses by the watch: mine, to the best of my judgment by feeling it, beat at the rate of 100 pulsations in a minute, near the end of the first experiment; and Dr. SOLANDER's made 92 pulsations in a minute soon after we had gone out of the heated room. Mr. BANKS sweated profusely, but no one else; my shirt was only damp at the end of the experiment. But the most striking effects proceeded from our power of preserving our natural temperature. Being now in a situation in which our bodies bore a very different relation to the surrounding atmosphere from that to which we had been accustomed, every moment presented a new phenomenon. Whenever we breathed on a thermometer the quicksilver sunk several degrees. Every expiration, particularly if made with any degree of violence, gave a very pleasant impression of coolness to our nostrils, scorched just before by the hot air rushing against them when we inspired. In the same manner our now cold breath agreeably cooled our fingers whenever it reached them. Upon touching my side, it felt cold like a corpse; and yet the actual heat of my body, tried under my tongue, and by applying closely the thermometer to my skin, was 98° , about a degree higher than its ordinary temperature. When the heat of the air began to approach the highest degree which this apparatus was capable of producing, our bodies in the room prevented it from rising any higher; and when it had been previously raised above that point, inevitably sunk it. Every experiment furnished proofs of this: toward the end of the first, the thermo-

meter was stationary : in the second, it sunk a little during the short time we staid in the room : in the third, it sunk so fast as to oblige us to determine that only one person should go in at a time : and Mr. BANKS and Dr. SOLANDER each found, that his single body was sufficient to sink the quicksilver very fast, when the room was brought nearly to its *maximum* of heat.

These experiments, therefore, prove in the clearest manner, that the body has a power of destroying heat. To speak justly on this subject, we must call it a power of destroying a certain degree of heat communicated with a certain quickness. Therefore in estimating the heat which we are capable of resisting, it is necessary to take into consideration not only what degree of heat would be communicated to our bodies, if they possessed no resisting power, by the heated body, before the equilibrium of heat was effected; but also what time that heat would take in passing from the heated body into our bodies. In consequence of this compound limitation of our resisting power, we bear very different degrees of heat in different mediums. The same person who felt no inconvenience from air heated to 211° , could not bear quicksilver at 120° , and could just bear rectified spirit of wine at 130° ; that is, quicksilver heated to 120° furnished, in a given time, more heat for the living powers to destroy, than spirits heated to 130° , or air to 211° (*Q*).
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(*f*) These numbers are the result of some experiments which were made on the first of February, in a room where the heat of the air was 65° . Mr.

BANKS.

And we had in the heated room where our experiments were made, a striking though familiar instance of the same. All the pieces of metal there, even our watch-chains, felt so hot, that we could scarcely bear to touch them for a moment, whilst the air, from which the metal had derived all its heat, was only unpleasant. The slowness with which air communicates its heat was further shewn, in a remarkable manner, by the thermometers we brought with us into the room, none of which at the end of twenty minutes, in the first experiment, had acquired the real heat of the air by several degrees. It might be supposed, that by an action so very different from that to which we are accustomed, as destroying a large quantity of heat, instead of generating it, we must have been greatly disordered. And indeed we experienced some inconvenience; our hands shook very much, and we felt a considerable degree of languor and debility; I had also a noise and giddiness in my head. But it was only a small part of our bodies that exerted the power of destroying heat with such a violent effort as seems necessary at first sight. Our cloaths, contrived to guard us from cold, guarded us from the heat on the same principles. Underneath we were surrounded with an atmo-

BANKS and I found that we could bear spirits which had been considerably heated and were now cooling, when the thermometer came to the 130th degree; cooling oil at 129°; cooling water at 123°; cooling quicksilver at 117°. And these points were pretty nicely determined; so that though we could bear water very well at 123°, we could not bear it at 125°, an experiment in which **Dr. SOLAN- DER** joined us. And our feelings with respect to all these points, seemed pretty exactly the same.

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sphere of air, cooled on one side to 98° , by being in contact with our bodies, and on the other side heated very slowly, because woollen is such a bad conductor of heat. Accordingly I found, toward the end of the first experiment, that a thermometer put under my cloaths, but not in contact with my skin, sunk down to 110° . On this principle it was that the animals, subjected by M. TILLET to the interesting experiments related in the Memoirs of the Academy of Sciences for the year 1764, bore the oven so much better when they were cloathed, than when they were put in bare: the heat actually applied to the greatest part of their bodies was considerably less in the first case than in the last. As animals can destroy only a certain quantity of heat in a given time, so the time they can continue the full exertion of this destroying power seems to be also limited; which may be one reason why we can bear for a certain time, and much longer than can be necessary to fully heat the *cuticle*, a degree of heat which will at length prove intolerable. Probably both the power of destroying heat, and the time for which it can be exerted, may be increased, like most other faculties of the body, by frequent exercise. It might be partly on this principle that, in M. TILLET's experiments, the girls who had been used to attend the oven bore, for ten minutes, an heat which would raise FAHRENHEIT's thermometer to 280° : in our experiments, however, not one of us thought he suffered the greatest degree of heat that he was able to support.

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A principal use of all these facts is, to explode the common theories of the generation of heat in animals. No attrition, no fermentation, or whatever else the mechanical and chemical physicians have devised, can explain a power capable of producing or destroying heat, just as the circumstances of the situation require. A power of such a nature, that it can only be referred to the principle of life itself, and probably exercised only in those parts of our bodies in which life seems peculiarly to reside. From these, with which no considerable portion of the animal body is left unprovided, the generated heat may be readily communicated to every particle of inanimate matter that enters into our composition. This power of generating heat seems to attend life very universally. Not to mention other well known experiments, Mr. HUNTER found a carp preserve a coat of fluid water round him, long after all the rest of the water in the vessel had been congealed by a very strong freezing mixture. And as for insects, Dr. MARTINE ^(g) observed, that his thermometer, buried in the midst of a swarm of bees, rose to 97°. It seems extremely probable, that vegetables, together with the many other vital powers which they possess in common with animals, have something of this property of generating heat. I doubt, if the sudden melting of snow which falls upon grass, whilst that on the adjoining gravel walk continues so many hours unthawed, can be adequately explained on any other supposition. Moist dead

(g) *Essays Medical and Philosophical*, p. 331.

sticks are often found frozen quite hard, when in the same garden the tender growing twigs are not at all affected. And many herbaceous vegetables, of no great size, resist every winter degrees of cold which are found sufficient to freeze large bodies of water. It may be proper to add, that after each of the above mentioned experiments of bearing high degrees of heat, we went out immediately into the open air, without any precaution, and experienced from it no bad effect. The languor and shaking of our hands soon went off, and we have not since suffered the least inconvenience.