V. *Miscellaneous Observations on Animal Heat.*

By JOHN DAVY, *M.D., F.R.S., L. and E.*

Received November 2,—Read December 14, 1843.

I. *On the Temperature of the Pelamides* (*Pelamys Sarda*, CUV. and VAL.).

FISHES generally are commonly considered as cold-blooded. In a work published in 1839, I have stated particulars tending to show, that this commonly received opinion is not universally correct, and that fishes of the genus Thynnus, with some others of the Scomber family, may be inferred to be an exception*.

As this inference was founded chiefly on the reports of fishermen, it appeared very desirable to determine by actual thermometrical measurement what is the exact temperature of fishes of this family.

Hitherto, although watching for opportunities, and promised the aid of friends favourably situated, I have not been able to make any observations of the kind required, excepting on one species of these fishes, the Pelamides, the *Pelamys Sarda* of CUVIER and VALENCIENNES. The Pelamides, like most of its congeners, is migratory in its habits. In the early part of summer it appears in the sea of Marmora and the Bosphorus, and in August in the Black Sea, from whence, after spawning, it returns in September and October, on its passage to the Mediterranean. It is caught in the same manner as the Tunny.

In June 1841, whilst at Constantinople, I visited a fishing station for this fish, in an inlet of the sea of Marmora, and was present when a small capture was made, enabling me to ascertain the temperature of four specimens. This was done the instant they were taken out of the water, being in a boat alongside the net, by introducing a thermometer with a projecting bulb, through a small incision, into the muscle of the back, about an inch and a half, and immediately after into the cavity of the abdomen. In three instances, the thermometer in the back rose to 75° FAHR.; in one to 74°; in all, in the abdomen it rose to 73°. The Pelamides were of moderate size, between two and three feet long. The air at the time was 71°; the sea at the surface 68°; but probably at the depth from which the fishes were taken, it was a few degrees lower, the descending current of the Bosphorus then being, where coldest, at 62°.

Supposing that the water from which they were taken was 62°,—and it might have been lower, as the Pelamides swim in deep water,—the temperature of this fish would appear to be about 12° above the medium in which it swims, and at least 7° above that of the surface.

* Researches, Physiological and Anatomical, vol. i. p. 218.

This result seems in accordance with the inference, that all fishes are not cold-blooded. In the work already referred to, reasoning from the smaller size of the respiratory nerves of the *Pelamys Sarda*, compared with those of the Tunny, I offered the conjecture that its temperature would be found less than that of the Tunny, and somewhat higher than that of fishes of other orders with still smaller respiratory nerves, a conjecture which the observations described may be adduced as confirming.

In connexion with their temperature, my attention was directed to the blood of these fishes. I have been able to examine it only in three instances, and that partially, viz. the Sword-fish, the *Pelamys Sarda*, and the common Tunny. Considering the great difficulty there is in obtaining the subjects for experiment under favourable circumstances for examination, imperfect as were my results, I am induced to offer them now.

The Sword-fish appears to abound less in blood than the Pelamides, and the Pelamides less than the common Tunny; and accordingly the muscles of the former two are of a much lighter colour than those of the latter.

The blood of the Tunny is very rich in red particles: this is indicated not only by its appearance, but also by its specific gravity, which I have found as high as 1·070. The blood tried was taken from a fish, caught in the sea of Marmora, that weighed between two and three hundred pounds.

The blood of the Pelamides appears to be less rich in red particles than that of the Tunny, but more than that of the Sword-fish: I have not ascertained its specific gravity. The specific gravity of the blood of the Sword-fish I have found to be 1·051; the fish from which the blood was taken was caught in the Bosphorus, in the month of December, and was of large size.

Under the microscope the appearance of the red particles of the blood of these three fishes is very similar. They are commonly thin oval discs (very soft), containing oval nuclei: a few circular discs are intermixed with them. The medium dimensions of those of the Pelamides were about $\frac{1}{2000}$th of an inch by $\frac{1}{3000}$th; of the Sword-fish, about $\frac{1}{3000}$th by $\frac{1}{4000}$th; and of the Tunny, about $\frac{5}{8000}$th by $\frac{3}{8000}$.

That the red particles constitute that portion of the blood which is chiefly concerned in the production of animal heat, is now generally admitted. What a contrast appears, in comparing the blood of the fishes under consideration, with that of some of the colder, especially of the cartilaginous kind, in which it is very small in quantity, accompanied by a proportionally diminutive heart, and poor in red particles! the blood of the *Squalus Acanthias* I have found to exceed in density only a little its serum, one being of the specific gravity 1·030, the other of the specific gravity 1·027.

Whether the peculiar constitution of the red particles operates in any way in promoting their union with oxygen, seems to be deserving of consideration. It may be thrown out as a conjecture, that the circumstance of their possessing nuclei may

have an effect of the kind, supposing, which is possible, the blood-corpuscle and nucleus, or containing and contained part, to be in the electrical relation to each other of positive and negative. If it be objected to this, that as regards nuclei as well as size, there is an analogy between the blood-corpuscle of fishes, birds and reptiles, the temperature of which commonly is so very different, it may be answered, that in all these classes such a constitution of blood-corpuscle may be designed for the same end, and that birds partly owe their high temperature to it; and that in reptiles and fishes, in most of which the proportion of red particles is small, were the constitution of blood-corpuscle different, it would be inadequate to perform the part required of it.

II. *On the Temperature of Man in advanced age.*

Not aware of any observations having been published on the temperature of man in advanced old age, I have been induced to institute some trials, the results of which I shall now briefly describe.

1. 91 years of age; feeble on his legs, but in pretty good health; a native of Grasmere in Westmoreland, where he has always resided, in easy circumstances, cultivating his own land. In June, when the temperature of the air was 60°, a thermometer placed under the tongue rose to 99°·5; his hands were warm; his pulse at the wrist 48, strong, intermitting. The observation was made at 2 P.M.; he had dined at noon. On the 28th of the October following, his temperature was again tried, about the same time of day, when the open air was 42°, the air of his room 52°; now, under the tongue, the thermometer was 98°·5; the pulse 56; his state of health much the same as before.

2. 88 years of age, also a native of Grasmere, where he has mostly resided, as a day labourer; is pretty firm on his feet, but troubled with chronic cough and difficulty of breathing. In June, when the temperature of the air was 60°, a thermometer placed under the tongue rose to 99°·5; his pulse was 56, and rather feeble; he had dined three hours previously. On the 28th of October, an hour after dinner, when his pulse was 70, the thermometer under the tongue was 98°; the air of the room 55°. In February, about three hours after dinner, when his pulse was 44 and feeble, the temperature under the tongue was 96°. This was on the 27th, the air then of his room was 44°; the open air about 32°, after a heavy fall of snow, and a sharp frost of several days' duration. The old man was feebler than in the summer and autumn; and though he did not complain of cold, his hand felt cold.

3. The wife of the preceding, the mother of several children, 76 years of age; hale for her years, but blind from cataract complicated with amaurosis. Her temperature, tried at the same time as her husband's, in June, was found under the tongue to be 98°·5, her pulse 78, and pretty strong. Tried again in October, it was found to be 98°, with a pulse of 70; and again in February, on the 27th, it was found to be 99°; her pulse being 80.

4. 87 years of age, a native of Ambleside, where she has commonly resided; feeble, but, excepting chronic cough, in tolerable health. On the 26th of October, at 3 P.M., the temperature under the tongue was found to be 98°·5; her pulse 84, and pretty strong; the air of the room then was 57°, the open air about 42°.

5. On the same day, and in the same village, tried the temperature of another old inhabitant, 92 years of age. The thermometer under her tongue stood about 98°; it could not be determined with perfect exactness, on account of the tremulous motion of her head, which also affected the limbs, preventing the counting of her pulse; her general health was pretty good.

6. An inhabitant of Ambleside, by trade a hatter, 89 years of age, hale, able to walk to church. On the 27th of October, when the air of his room was 56°, the outer air 42°, his pulse 64, strong and regular; the thermometer under his tongue stood at 98°. Observed again on the 27th of February, at 1 P.M., just after dinner, when the outer air was 32°, the air of his room 54°, the temperature under his tongue was found to be 99°·5; his pulse 70.

7. The temperature of his wife, two years younger, taken on the 27th of October, was 98°·5; her pulse was 88, irregular; she was very infirm and suffering from asthma.

8. A native of Scotland, 95 years of age, now residing in Ambleside, where he has been many years, always in good health, still tolerably strong and active. On the 28th of October found his temperature under the tongue 98°·5; his pulse 56, intermitting; the air of his room 57°. The old people in all the preceding instances, at the time the observations were made, were sitting by their fireside, as is their usage in the cool climate of Westmoreland, the greater part of the year, and all of them, with one exception, seemed to be comfortably warm; the poorest of them were not in want.

Old age is commonly represented as cold, and the temperature of the body is commonly supposed to diminish with advancing age. The results of the preceding observations generally are not in accordance with this opinion; they seem on the contrary to show, that the temperature of old people, at least as regards the deep-seated parts, of which the tongue at its base may be considered as some indication, is rather above than below the average temperature of middle age, taking that to be about 98° of FAHR. Nor, perhaps, is this surprising, when we reflect, that most of the food consumed by old persons—and their appetite generally is good—is probably chiefly employed in administering to the function of respiration, being very partially expended in meeting the waste of the body.

Probably in very advanced old age, as in very early infancy, the power of resistance to cold is feeble, and the temperature of the body is easily reduced on exposure. An observation which I made many years ago in Ceylon would seem to be confirmatory of this. At 7 o'clock in the morning, when the air was 72°, I tried the temperature of an old man, almost a century old, and of a boy about twelve years old, both cool, being thinly clad and out of doors; the temperature of the old man under the tongue was 95°; in the axilla 93°; that of the boy under the former 98°, and in the

latter 96°·5. The observation too on the old man in Grasmere, made in February in cold weather, is also favourable to this conclusion: whilst those made at the same time, on the other two old persons in stronger health, seem to show, that, provided there is a vigorous action of the heart and free circulation of the blood, the temperature of the body is easily maintained.

III. *On the Effect of Air of different Temperatures on Animal Heat.*

As from observations made on man on entering the tropics, and within the tropics on descending from a cool mountainous district to a hot low country, it would appear that his temperature as measured by a thermometer placed under the tongue is liable to fluctuate,—rising one or two degrees in a warm atmosphere, and falling as much on entering a cool one *,—it seemed probable that like differences of effect might be produced by air kept at different degrees of temperature in buildings in this country.

In the autumn of last year, when going through the cotton manufactory of Deanstone, in the neighbourhood of Doune in Stirlingshire,—an establishment admirably conducted and in the highest order,—I availed myself of the opportunity to try the temperature of a few individuals in relation to this question. In the room called the "piecing-room," where a high temperature is always required on account of the kind of work,—a temperature kept up by means of warm air and steam,—when at 92°, I found the thermometer placed under the tongue of one man who had been at work there about six hours, rise to 100°·5; and of another, who had been there the same time, to 100°: the former was 52 years of age, healthy, his pulse 64; the other 33 years of age, in pretty good health, but liable to acidity of stomach; his pulse 78.

In an adjoining room, where the temperature of the air was 73°, the thermometer placed under the tongue of a young woman rose to 99°; and in a large room, where 300 persons were employed in weaving, and where the temperature of the air was 60°, the thermometer placed under the tongue of another healthy young woman rose only to 97°·5.

Few as are these observations, they seem to warrant the conclusion that a high temperature of even a few hours in the heated air of a room is capable of raising the temperature of the body above its usual standard, in accordance with what had been anticipated from the effect of different degrees of atmospheric temperature.

In further confirmation of the same, I may briefly state the results of multiplied observations made on the temperature of the same individual. The subject of them was of middle age, in good health, under whose tongue the thermometer commonly was stationary at 98°, when neither suffering from heat nor cold. The place where they were made was Constantinople,—the climate of which capital, it may be observed, is exceedingly variable,—often cold in winter and the early spring, and commonly very hot in summer,—liable to great vicissitudes from its situation on the

* *Op. cit.* i. 169.

confines of two seas, in regard to warmth very different in character during a great part of the year. The observations were begun early in March, and were continued at intervals till the latter end of July. During this time the thermometer in the open air ranged from 31° to 94°, and the temperature observed under the tongue from 97° to 99°·5. It may not be amiss to mention some particular instances.

On the 5th of March, after having been exposed several hours in an open boat on the Bosphorus, with a strong wind at 43°, the thermometer placed under the tongue stood at 97°.

On the 11th of the same month, when the ground was covered deeply with snow, and the thermometer in the open air at 7 A.M. was 31°, and in a bed-room 45°, the temperature under the tongue was found to be 97°·5.

On the 3rd of April, when the thermometer in the room, with the window open, was 66°, under the tongue it was 98°·5.

On the 17th of July, when the thermometer was 87°, under the tongue it rose to 99°·5. On the 21st of the same month, when the air was 87°, the temperature under the tongue was 99°·5 ; and on the 28th, when the former was 94°, the latter was 99°.

During the hot weather of July, it may be deserving of remark, that the pulse was less affected than the respiration, which habitually about sixteen in the minute, was now commonly fourteen, and one day did not exceed twelve.

It may also be mentioned that attention was paid to the temperature of the extremities, and also to that of the urine, and that commonly it was found of highest temperature when the tongue and extremities were of lowest temperature: thus, on the 5th of March, when the thermometer under the tongue was 97°, the feet and hands cold, in the urine it rose to 101°; and on the 28th of July, when under the former it was 99°·5, in the latter it was the same.

Do not these observations, besides tending to confirm the preceding conclusion for which they were brought forward, viz. that the temperature of the body rises and falls in a perceptible manner with the temperature of the air, lead also to the further conclusion, that the tendency of a high temperature of atmosphere is to raise the temperature of the surface and of the parts adjoining the surface in a somewhat higher ratio than the deep-seated organs; and of a low temperature of atmosphere to raise the temperature of the deep-seated parts, whilst that of the surface is subjected to undue reduction from the cooling agencies to which it is exposed, directed, as it were, in both instances, for a beneficial result, on the principle of compensation?

IV. *On the Effect of Exercise on the Temperature of the Body.*

This subject of inquiry, notwithstanding its manifest importance, has been much neglected; indeed, I do not know of any work in which any precise information is to be obtained respecting it.

The observations which I have to offer are fewer than I could wish and more limited; they were made at Constantinople in 1841, at intervals between February

and August, and had for their object mainly to endeavour to determine the effect of moderate exercise in walking on the temperature of the body. The individual on whom they were made was the same as was mentioned in the last section. The particular observations are the following:

February 19th, at $1\frac{1}{2}$ P.M., air of room 60°; before walking, feet cold, temperature between the toes 66°; under the tongue 98°; urine 100°. At $5\frac{1}{2}$ P.M., open air 40°; just returned from a walk, gently warmed by the exercise; feet and hands warm; the former 96°·5, the latter 97°; under the tongue 98°; urine 101°.

March 2nd, at $4\frac{1}{2}$ P.M., open air 50°; air of room 66°; feet and hands moderately warm; the former 75°, the latter 81°; under the tongue 98°; urine 100°. At $5\frac{1}{2}$ P.M., after having walked pretty quickly an hour, a gentle perspiration produced, the hands and feet hot, found the latter 99°, the former 98°; under the tongue 98°; the urine 101°·5.

March 20th, at $5\frac{1}{2}$ P.M., open air 42°; returned warm after a walk of three hours: the hands, which had worn warm gloves, were 99°; feet 97°; under the tongue 98°; the urine 101°·5.

April 7th, after a walk of three hours in the open air, between 60° and 70°, returned at 5 P.M., gently perspiring: the hands were 94°; the feet 96°·5; under the tongue 98°·5; the urine 100°·5.

May 27th, at $6\frac{1}{2}$ P.M., after a walk of an hour and half, the air 68°, returned slightly perspiring; the hands were 95°; the feet hot; under the tongue 99°·5; the urine 101°·5.

May 28th, air 65°; under the tongue before taking exercise 98°·5: after a walk of four hours and half, gently perspiring, under the tongue 98°; hands 93°; feet 97°·5; urine 100°·5.

September 13, at 4 P.M., the open air on the shore of the Bosphorus 76°: ascended in about twenty minutes, without stopping, the steep side of the hill, called the Giant's Mountain; on reaching its summit, when profusely perspiring, the pulse was 102°, usually about 52°; the hand 98°; under the tongue 98°. The pulse of another individual in company, of about the same age, also profusely perspiring, was 138°; thermometer under his tongue 98°; and in the hand the same. After descent, the pulse of the former was 94°; thermometer under his tongue and in the hand 98°·5; the pulse of the latter was 112°; the thermometer under his tongue 98°·5; both only gently perspiring.

What is the inference from these observations? Do they not seem to indicate that whilst moderate exercise promotes the diffusion of temperature and its exaltation in the extremities, it augments very little, if at all, the heat of the deep-seated parts? And considering the blood as the heating medium, warmed itself chiefly by respiration, is not this what might be expected, reasoning on the subject? By active exercise, the pulse and the respiration are both accelerated; more oxygen, it may be presumed, is consumed, more heat is generated; the blood is made to circulate more rapidly,

and is sent in larger quantity into the extremities, and where, in consequence, the excess of heat is conveyed and expended, and its accumulation in the central and deep-seated organs prevented, affording another striking example of harmonious adaptation.

The same thermometer was employed in making all the observations described in this paper; and in every instance, in stating the results, allowance has been made for error in its graduation, carefully determined by comparison with a standard instrument, one belonging to Professor FORBES of Edinburgh, and for the use of which I have been indebted to his kindness.

The Oaks, Ambleside,
Nov. 1st, 1843.