REPORT OF EXPERIMENTS UPON THE ANIMAL HEAT OF FISHES, MADE AT PROVINCETOWN, MASS., DURING THE SUMMER OF 1879, IN CONNECTION WITH OPERATIONS OF THE UNITED STATES FISH COMMISSION.

By J. H. KIDDER, Surgeon, U. S. NAVY.

SIR: The investigation of the manifestation of animal heat by fishes, with which you intrusted me last summer, having been brought to a pause for the time being by the close of the Fish Commission's summer work, I submit the following report of my experiments, so far as they have gone, with a description of the instruments used and the mode of observation.

But little in the way of actual experiment relating to this interesting question seems to have been done by other observers than those connected with the Fish Commission, although numerous allusions to the remarkable adaptability of fishes to extremes of temperature, and occasional records of more or less incomplete experiments, are to be found scattered through scientific literature. A complete bibliography of these fragmentary notes would be voluminous and of questionable value, but a short account of such observations as I have been able to find a record of, either interesting in themselves or of incidental value as throwing light upon the investigation, is appended to this report.

So far as I have been able to learn, all of the observations made hitherto upon the temperature of fishes have been confined to the intestinal canal, the thermometer being passed into the rectum or œsophagus, as is the usual practice in observations upon the body temperature of mammals. But the conditions are by no means the same. The intestinal canal of a fish is thin and scarcely muscular; the walls of the abdomen are also thin, and so sparingly vascular that no blood flows when they are cut through; and consequently, always surrounded as they are by water, against the chilling effect of which there is no sufficient protection, it is by no means in the rectum or stomach that we should reasonably look for the body temperature of a fish. In point of fact, the experiments to be hereinafter detailed show clearly enough that the rectum temperature of a freshly-taken fish rarely exceeds that of the water in which it swims by so much as a degree (Fahrenheit). So that it may be quite safely taken as an index to the latter temperature when there is no deep-sea thermometer at hand.

Another point to be considered is the fact that the gills of most fishes float freely in the surrounding water, and that all of the blood in each individual must, in passing through these organs, be spread out so as to expose the greatest possible surface to the chilling effect of the water quite long enough to reduce it to the same temperature.

From the low organization of fishes, and from the simplicity of their digestive and circulatory functions, considered together with the fact that their blood itself is chilled by close proximity with the surrounding water at least once in each circuit, and that thus the oxidation of the blood, so important a source of animal heat in mammals, is quite neutralized, we ought not to expect so great a difference in temperature between the blood of a fish and the water in which it swims as obtains between the blood of mammals and the surrounding medium, nor that the limits within which its normal temperature must be confined should be so narrow.

And, while it is difficult to believe that the chemical changes necessary to the nutrition, waste, and repair of the body of a fish, taken together with its active muscular movements, can go on without the evolution of a large amount of animal heat; it is also plain that we are not to expect to find the manifestation of this heat either in the intestinal canal, a mere osmotic tube for the passage and absorption of the food, scarcely vascular and barely separated from the surrounding water by the thin bloodless walls of the abdomen; nor in the arterial blood returning from the gills, chilled down to the temperature of the water with which it has just been in intimate contact.

We should expect to find the blood of a fish at its warmest after having been distributed to the substance of the body, having furnished the material for nutrition, taken up the results of waste, and received the heat developed by these processes and by the conversion of muscular motion; that is to say, in the heart and branchial artery.

The experiments to be described have been tentative for the most part, and accordingly temperatures have been taken in the rectum, the stomach, various parts of the muscular tissue, the large venous trunks, the cavity of the "thorax"* after opening the heart, the interior of the heart and branchial artery, and the young fish in the ovary (of a dog-fish). When the heart was large enough to admit the bulb of the thermometer, the greatest differences between the temperatures of the fish and of the surrounding water were found in that locality.

INSTRUMENTS.

The thermometers used in these experiments were made expressly for the purpose by Mr. John Tagliabue, of No. 66 Fulton street, New York; and have proved to be very satisfactory. They are fifteen in number, viz:

1. Two long thermometers, graduated in fifths of a degree, and covering the range from 32° to 100° F., for use as standards.

2. A set of five short thermometers, graduated in fifths, marking 10° each, and covering all together the range from 40° to 90° F.

3. A second set of six short thermometers, similar to those last named, marking from 7° to 15° each, and covering the range from 30° to 100° F.

4. A short thermometer with the end carrying the bulb curved upon

* The term "thorax" is used for convenience' sake, as indicating the anterior part of the body cavity, in the neighborhood of the heart.

itself like a crook, graduated in fifths and marking from 55° to 74° F. (self-registering).

5. A Negretti-Zambra deep-sea thermometer, graduated in degrees only, and ranging from about 25° to 100° F.

All of these excepting the Negretti-Zambra are graduated upon the stems. The three highest in range of lot 2, one of the long standards, and the crooked instrument were made at first self-registering, on the principle of clinical thermometers, by a break in the column of mercury. They were so ordered in the hope that it would be possible to make some of the experiments upon living fish in tanks where the water could be artificially warmed above the temperature of the air. Such experiments not being possible (for reasons known to you) the self-registration was destroyed by reuniting the broken mercury column, and the necessary small correction applied. The curved thermometer was intended for use in a living fish, the bulb to be inserted either into the rectum or into an incision in the muscular tissue, and the stem to be secured to the body of the fish, which was then to swim free in the water. The highest temperature reached would be registered by the thermometer. This instrument, like the other self-registering thermometers operating on the same principle, can only be made available when the temperature of the water is above that of the air, and there has, therefore, as yet been no opportunity to make use of it.

Owing to the curious molecular change which occurs in the glass of which thermometers are made, whereby, after from six months to a year, the instruments show an error of excess of from half a degree to a degree, these thermometers, which were necessarily "pointed" as soon as made, are not strictly accurate. They should be returned to the maker and rated again before being used next summer, so that the necessary correction may be applied. For the time being the error has been to some extent met by Mr. Tagliabue, who has "overpointed" the scale about half a degree. I would also suggest the propriety, in case you conclude to continue temperature-observations, of ordering in advance one or two long thermometers, marking from 30° to 100° F., to be "pointed" after six months and used as absolute standards. Since, however, in these observations, absolute temperature is less important than *relative* accuracy, I have taken much pains to rate all the instruments together, comparing them with the standard, and applying such corrections as will reduce all the readings to its scale. The same error, if any, will then be present in all observations, and *relative* accuracy will be preserved. In Table A, which contains the corrections deduced from more than three hundred separate comparisons taken at nearly every degree on the scale, the small thermometers in daily use are numbered from 1 to 5 for the first set, and from 6 to 12 for the second set (which has not yet been used), No. 1 being the thermometer of lowest scale. The comparisons were made by immersing the thermometers in water, artificially cooled or heated. Only the means of each 10° are given in the table.

No. 1 of the small thermometers and Negretti & Zambra's Nos. 43230 (between 70° and 80°), 38982, 40007, 42666, and 43227 (between 70° and 90°), are the only ones to which it is worth while to apply a correction in practice. The other differences, being less than half a degree, may be disregarded as not likely to exceed the ordinary errors of observation.

TABLE A.—*Thermometer corrections.*

Thermometer.	30°–40°	40°–50°	50°–60°	60°–70°	70°–80°	80°–90°	90°–100°
No. 1		Add 0.88°					
No. 2			Subtract 0.05°				
No. 3				Subtract 0.125°			
No. 4					Correct.		
No. 5						Subtract 0.13°	
No. 6	Correct.						
No. 7		Correct.					
No. 8			Correct.				
No. 9				Correct.			
No. 10					Subtract 0.7°		
No. 11						Correct.	Correct.
N. & Z., 38982		Add 0.86°	Add 1°	Add 0.7°			
N. & Z., 40007	Correct.	Add 0.5°	Add 0.5°	Add 0.5°	Add 0.5°	Correct.	Add 1°
N. & Z., 42666	Correct.	Add 0.5°	Add 1°	Add 1°	Add 0.5°	Correct.	Add 1°
N. & Z., 43230		Add 0.125°	Add 0.07°	Add 0.366°	Add 0.425°	Add 0.5°	
N. & Z., 43227		Add 0.35°	Add 0.05°	Add 0.236°	Add 0.5°	Add 0.5°	

There are some practical difficulties in the use of these delicate instruments, which it is well to mention.

1. The bulbs are long and large compared to the diameter of the column of mercury. Hence the latter is very sensitive and responds quickly to the heat of the hand, even through the walls of the heart, or, in small fishes, of the abdomen. Thus in a small living blue-fish (*Pomatomus saltatrix* (Linn.), Gill), observed September 8, in an aquarium-tank, the water being at 67° F., a thermometer passed into the stomach by way of the gullet showed 68.8°; but, holding the fish in my left hand, I observed that the mercury was slowly rising and had reached 73° in two minutes. This accession of heat was communicated through the thin walls of the abdomen from my hand.

2. Owing to the extreme fineness of the mercurial column it is quite difficult to distinguish it at all from the empty part of the tube, unless the light falls upon it at exactly the proper angle. When taking the temperature of a struggling fish on the deck of a vessel, in the full glare of the sun, and with the thermometer perhaps smeared with blood, it is impossible to be too careful in guarding against errors of observations.

3. A difference of several tenths may be apparent in the reading according to the position of the observer. Looking down upon the column he reads too low; looking up, too high. His eye should be exactly opposite the top of the mercurial column. After use, the thermometer should be wiped perfectly clean and laid back in its proper bed in the case, lest in the hurry of the next observation the wrong one be taken up, and time lost.

4. The Negretti-Zambra deep-sea thermometers, which depend for their self-registration upon the breaking of the mercurial column at a certain place when the instrument is overset in pulling it up, have sometimes a trick of breaking the column in the wrong place, and so giving a false indication. In one instance I noticed that the break was diagonal, instead of being directly horizontal, as it should have been. Professor Hind, of Halifax, informs me that he has noticed the same defect and has brought it to the notice of the makers, who have assured him that it has been corrected in their more recent form of instrument. It should also be always remembered that the temperature recorded by these instruments is not that of the bottom, but of about a fathom above it, owing to the play of line required in attaching them to the sounding-line so that they may overset easily and not strike against the lead.

MODE OF OBSERVATION.

The circumstances of the summer's work are too well known to you to require repetition here. In explanation of the small number of observations (ninety-seven for the whole summer) it will be sufficient to refer to the unusual inclemency of the season, permitting not more than an average of two excursions a week; and to the remarkable scarcity of fish, which made a large proportion of the excursions blank as to results. Many fishes were brought up in the trawl-net of the Speedwell (the naval steamer used by the Fish Commission), but had been so long in the net, pressed upon by each others' weight, as to come up for the most part dead; and always showing by their rectum temperature (which should be near that of the bottom) that they were not in their normal condition as to animal heat. Such observations as were taken from these specimens are entered in the table (B), but are not trustworthy for the purposes of this investigation. On one occasion I set a trawl-line furnished with some four hundred hooks, and took it in as soon as set. Although not more than twenty minutes had elapsed between setting and hauling, however, most of the fishes taken were already drowned, and all had lost a large proportion of their animal heat. Since, therefore, no tanks of sufficient size for keeping fishes alive under observation were available, there remained only line fishing, which was carried on during the latter part of the summer as actively as the weather would permit, from the yacht Phantom, belonging to the Engineer Corps of the United States Army, and lent to the Fish Commission for the summer. The fish were all taken in Cape Cod Bay, and within ten miles of Provincetown, the two favorite localities being the steep edge of a shoal known as "Shank-Painter Bar," between Wood End and Race Point lights, and a ledge in 15 fathoms of water some seven miles southwest of Wood End light.

The rectum temperatures indicate, and I have no reason to doubt, that a fish caught with a line and hauled rapidly from the bottom to the vessel's deck has not had time to materially change its temperature. The rectum usually showed from half a degree to a degree above the temperature near the bottom as indicated by a deep-sea thermometer.

Having arrived on the ground and anchored, the first proceeding was to sound and take the temperature of the water near the bottom by means of a Negretti-Zambra thermometer attached to the sounding-line, about half a fathom above the lead. The temperatures of the surface water and of the air were then taken with the same thermometer, and, where the depth exceeded 20 fathoms, another observation was made at 15 fathoms for subsequent comparison. As soon as a fish had been taken it was seized and held firmly by an assistant, his right hand grasping the throat under the gill-covers and his left holding the narrowest part of the tail, while I passed a thermometer into the rectum and observed the temperature of that part. I then cut the fish open from the isthmus between the gills toward the belly, exposing the heart, through the walls of which the thermometer was passed into the branchial artery and the temperature taken again. In this last manœuvre the heart should not be held between the finger and thumb of the left hand any longer than necessary to pass the thermometer-bulb into the artery, lest heat be communicated from the hand through the walls of the heart and give too high a reading. Then followed observations upon the temperature of the muscular tissue or other parts, when such were taken. When the fish was too small to admit the bulb of the instrument within the heart an effort was made to take the temperature of the blood as it flowed from it, or the temperature of the liver was taken, or, in very small fishes, the thermometer was passed into the stomach, through the œsophagus.

The above procedure is that finally adopted, after reflection upon the unsatisfactory results following observations made in the ordinary way (in the rectum). As to the cruelty of the operation, I am inclined to believe that it is more apparent than real, the fish showing no consciousness of pain, by struggling, &c., after the first incision.

RESULTS.

This summer's work must be considered to be, as I have said, only experimental. The subject had to be studied from the beginning, with no records of previous similar experiments to go by, and many observations were wasted in learning how to proceed. Enough has been ascertained, I think, to show that fishes do develop animal heat by their own vital processes in the same manner as, but to a less degree than, other vertebrate animals. In other words, it appears from these experiments that when proper precautions have been observed in making the experiments all living freshly-caught fishes will be found to manifest a body temperature differing considerably from that of the water in which they swim; the degree of difference varying with the perfection of the organization of the fish (and hence the activity of its nutrition), and with the temperature of the water in which it swims. Thus the dogfish (*Squalus acanthias*, Linnæus) possessing a far more perfect digestive and circulatory system than the cod, shows a much greater excess of blood temperature above that of the surrounding water; and cod taken at the depth of 15 fathoms in water at 52° F., show a less excess than others taken in 25 fathoms at 41°, but a greater excess than blue-fish (*Pomatomus saltatrix* (Linn.) Gill) taken at the surface, at 69° and 70°, which is presumably nearer the normal temperature of the last-named fish.

Upon this question of normal temperature, my observations have not thrown much light, owing to the fact that nearly all the fishes observed have come from water at about the same temperature, and that blue-fish, from which the most valuable results were to be expected on account of their activity and the warmth of the water which they inhabit, could not be taken with a line after the two days of their first appearance. It is reasonable to suppose, from the fact that the cod, for instance, shows a less difference when taken from warmer than from cold water, that a point would soon be reached at which the temperature of the blood of the fish would coincide with that of the surrounding water, and that this point would be near the "normal" for that family, or in other words the limit above which it could not live.*

The experiments are set forth at length in Table B, but some of the conclusions for which they furnish a reasonable basis may be conveniently stated here, considering each species separately.

1. Cod (*Gadus morrhua*, Linnæus). Twelve observations. The fishes were taken with a hand-line, either at the edge of "Shank-Painter Bar," a sand-bank about half a mile wide which makes out along the end of Cape Cod from Race Point to Wood End light-house, in 22–25 fathoms of water, or on the "Ledge," a small rocky shoal lying about seven miles WSW. from Wood End light, where there are from 13 to 15 fathoms of water, according to the state of the tide. The rectum showed an average excess of 0.97° above the temperature of the water near the bottom. In the bloody fluid resulting from the mixture of water with the blood escaping from the heart into the "thorax," the average excess of temperature was 3°, and in the heart itself 4.63°. In one instance an incision was made into the side of a very large cod, from which *arterial* blood gushed forth. A thermometer plunged into this incision showed only 1.5° excess over the temperature of the water near the bottom. It was this observation which suggested the thought that the venous blood might be warmer than the arterial.

*Prof. G. Browne Goode, who has been investigating the question of the temperatures preferred by different fishes, concludes that the cod and its congeners seek water at 38° to 42° F.; that the temperature range of menhaden lies between 50° and 75°; that blue-fish are rarely to be found in water below 40°, or mackerel below 45°; while black bass (*Micropterus*) thrive in the water of the northern lakes, frozen over for three months in the year and never rising above 65°, as well as in that of the Florida rivers, which becomes as warm as 90° in summer. Different families, as thus appears, show very different powers of adaptation to extremes of temperature.

2. HADDOCK (*Melanogrammus æglefinis* (Linn.), Gill). Eight observations. The rectum showed an average excess of 1.3° over the temperature of the water near the bottom, and the circulation an average of 5.3°. One fish, after ten minutes spent in a tub of water at 64.2°, showed an increase of temperature in the rectum of 7°. Another, which had been tied by the tail and allowed to swim 15 minutes at the surface (at 69.5°) showed an increase (in the rectum) of 16.8°; still 11.5° below the temperature of the water. On the 6th September, fishing on the "Ledge," the temperature of the water near the bottom at 15½ fathoms was 51.5°, while the recta of the first two or three fishes caught showed as low a temperature as 45°. Those caught later, after fishing in the same place for an hour or more, showed a rectum temperature of 51°. I suppose that the individuals first taken (the tide having just turned to flood) came up on the ledge from deeper water, the ledge being of small extent, and showed the low temperature of the water from which they had come, gradually approximating that of the shallower water as they remained longer in it. These first temperatures are left out of the account in determining the above averages, as untrustworthy, owing to the uncertainty of the temperature of the water by which they had been surrounded. Haddock were spawning as early as the first observations (July 30), which fact may account for their somewhat higher temperatures than those of cod taken at the same time.

3. POLLACK (*Pollachius carbonarius* (Linn.), Bonaparte). A single full-grown specimen, weighing about 25 pounds, was taken on the "Ledge" in 15 fathoms. The rectum temperature was 2.4° above that of the water near the bottom (42°), and that of the fluid in the thorax after opening the heart, 4.5°. Several of the young of this species were taken from the wharves of Provincetown at different times and examined. Seven specimens taken from a depth of 8 feet (temperature of water 60°), and measuring about 8 inches in length, showed an excess of 0.5° in the rectum, 0.6° in the stomach (passing the thermometer through the gullet), and 3.12° by the thermometer in the mass of intestines, &c., next the liver. They were in company with "tinker mackerel" (*Scomber Dekayi*, Storer), of a species not observed in this harbor for more than thirty years.

4. HAKE (*Phycis chuss* (Walb.), Gill). This fish was often taken at the same time with cod and haddock. Specimens were frequently brought up, dead, in the trawl-net. Those taken with a line were often too small for trustworthy experiment, but a very large individual, weighing over 35 pounds, taken August 11, in 25 fathoms of water, at 42°, furnished the most satisfactory observation of the season, owing to the large size of the heart and the sluggishness of the fish, which made it much easier than usual to be sure of the readings. In this instance the difference in temperature of the water near the bottom and that of the rectum was 2.4°, and between the bottom water and the heart, 9.8°. There was an ulcerated patch about 2 inches square on the side of the

head. Could this have been the cause of the unusually high temperature? The presence of spawn in the abdomen protected the rectum to some extent, no doubt, from the chilling effect of the water. Another specimen taken in 15 fathoms on the "Ledge" gave a difference of 3° between the temperatures of the rectum and heart, the bottom temperature being uncertain for reasons already stated. (See page 313.)

5. BLUE-FISH (*Pomatomus saltatrix* (Linn.), Gill). These were caught on only two occasions, although often fished for unsuccessfully. Four specimens on the first day and one on the second were taken by trolling, and brought in after violent resistance. The average rectum temperature of the first four was 0.25° *higher*, and the temperature obtained by an incision into the muscles of the side 1.55° *lower* than that of the surface water from which the fish came (73.2°). The surface water was unusually warm on this occasion, and the fishes may have come from a deeper and colder stratum. Otherwise the indication would appear to be that they *resisted* in some way the higher temperature than that to which they were accustomed. They were taken from different schools and at different times. The single fish taken on the following day showed a rectum temperature of 0.5°, and in the muscles of the side 1.7° *above* that of the surface water (70.5°). The muscles of the side of this last fish, however, were only 0.5° warmer than the average (71.5°) of the four taken the day before. At this time I had not yet begun to observe the temperature of the blood in the heart and branchial artery. Young blue-fish, 3 or 4 inches long, have been caught from the wharves at different times, but have been too small to afford trustworthy observations.

6. "TINKER MACKEREL" (young of *Scomber scomber*, Linnæus, and *Scomber Dekayi*, Storer). No fully-grown mackerel have been taken with the line in the neighborhood of Provincetown for several years. The "tinkers," however, from 6 to 8 inches long, abounded toward the last of the season, and upon these several observations were made at different times, the temperature of the surrounding water being taken at 6 feet below the surface, the length of line required in fishing. The anus was too small to admit the bulb of my thermometers, and temperatures were therefore taken in the stomach through the gullet, and in the immediate neighborhood of the liver after dividing the larger blood-vessels. The average of twelve observations gives an excess of temperature over that of the surrounding water of 4.1° in the stomach, and 5.25° in the neighborhood of the liver. The individual temperatures were surprisingly uniform. Three specimens of young *Scomber Dekayi*, taken from the wharf in 8 feet of water at 60°, showed an average excess of 2.3° in the neighborhood of the liver.

7. CHOGSET (*Tautogalabrus adspersus* (Walb.), Gill). Two observations were made upon a single small specimen in an aquarium-tank, the water being at 65.9°, and the thermometer passed into the stomach through the gullet. The excess of temperature over that of the water was 1.2°.

8. SCULPIN (*Cottus octodecimspinosus*, Mitchill). A single specimen showed an excess in the rectum of 0.8°, and in the neighborhood of the liver of 3.2° over the temperature of the surrounding water.

9. SEA-RAVEN (*Hemitripterus americanus* (Gmel.), Storer). A specimen kept alive in a tub on board of the Speedwell for three-quarters of an hour (the water marking 70.6°) showed an excess in the temperature of its circulation over that of the water of 4.4°. Another specimen brought up in the beam-trawl-net showed an excess in the rectum of 17.7° and in the heart of 18.9° over the temperature of the bottom water, but had been half an hour in the trawl, pressed closely on every side by a mass of fishes and sponges. So that the observation is valueless excepting in that it shows that even under abnormal conditions, so long as the fish lives, there is a difference between the temperature of the rectum and of the venous blood.

10. GOOSEFISH (*Lophius piscatorius*, Linnæus). This fish is admirably constructed for temperature experiments, being provided with a very large heart and branchial artery, and, moreover, with a highly organized digestive system. Unfortunately the only two specimens observed were brought up in the trawl-net with the above-named sea-raven, and had their body temperatures abnormally raised in the same manner. The difference in temperature between the rectum and the circulation was 4.4°.

11. EEL-POUT (*Zoarces anguillaris* (Peck), Storer). Two specimens taken in the trawl-net at the same time and under the same circumstances as the preceding showed a difference between the temperatures of the rectum and the circulation of only 0.5°, the fishes being almost dead. A single specimen taken afterwards with the hand-line showed an excess in the rectum of 3°, and in the neighborhood of the liver of 6°, over that of the surrounding water.

12. FLOUNDER (*Hippoglossoides platessoides* (Fabricius), Gill). In a single specimen taken on a trawl-line the temperature of the circulation was 3° above that of the water near the bottom.

13. DOGFISH (*Squalus acanthias*, Linnæus). This species was much the most abundant of any near Provincetown. Owing to the high organization of the digestive system of the order to which this fish belongs, it was to be expected that the heat resulting from the processes of nutrition would be found in it to be highest. Accordingly, as the table shows, the differences between the body temperatures and those of the surrounding water are here greater than those manifested by other fishes. In a series of five taken from cold water (40.4°) the average rectum temperature was 4.4° and that of the circulation 12° above that of the water near the bottom. The greatest difference occurred in a female, the ovaries of which contained well-developed young, in which case the circulation was 16.6° warmer than the surrounding water. A young dogfish about 9 inches long, with umbilical vesicle still attached, taken from this specimen, gave an excess of 20.6° in the heart above the temperature of the water, the greatest difference observed during the summer. In this young fish there was of course no cooling of the blood during its

passage through the gills (those organs not having yet come into use), nor otherwise than mediately through contact with the body of its mother. Another adult female with young in her ovisac showed an excess of 9.4° in the rectum (oviduct?) and 15.6° in the heart over the temperature of the water. In another series of fourteen observations upon specimens taken with a trawl-line, and half drowned when drawn up, the body temperatures had approximated that of the surrounding water. In this observation, too, the Negretti-Zambra thermometer failed to act, the column breaking in the wrong place, so that the temperature of the bottom water had to be guessed at from that of the recta of the fishes and from previous observations in the same neighborhood. It was probably not higher than 42°. Above this supposed bottom temperature the fourteen half-drowned dogfish gave an excess of 2.2° in the rectum and of 4.8° in the heart and "thorax." The greatest excess was 6.7°. Still another series of seven taken with a line on the "Ledge," when the indicated bottom temperature could not be relied on, for reasons already given (see p. 313), showed an average difference between the rectum and heart temperatures of 6.7°, while in another specimen the difference between the rectum and muscles was only 1.6°.

14. SKATE (*Raia erinacea and R. lævis*, Mitchill). Three individuals of the former species, which had been half an hour with a number of other fish in the trawl-net, and were therefore useless for comparison with the bottom water, showed an excess in the temperature of the blood over that of the rectum of 3.1°. Four individuals of the latter species (*R. lævis*) taken on the "Ledge," when the temperature of the water from which the fish came was unknown, gave a difference between rectum and circulation of 2.9°.

SUMMARY.

Throwing out doubtful and imperfect observations, the results of those experiments in which the circumstances were most favorable to accuracy, may be summed up as follows:

Fish.	Temperature of surrounding water.	Temperature of rectum above water.	Temperature of circulation above water.	Remarks.
Cod	39°–42°	0.98°	4.63°	
Haddock		1.3°	5.3°	
Pollack	42°	2.4°	4.5°	
Hake	42°	2.4°	9.8°	Spawning.
Blue-fish	73.2°	0.25°	1.55° below.	
Do	70.5°	0.5°	1.7° above.	
"Tinker" mackerel	65°	4.1°	5.25°	"Thorax."
"Tinker," *S. Dekayi*	60°		2.3°	Do.
Sculpin	60°	0.8°	3.2°	Do.
Sea Raven	70.6°		4.4°	Stomach.
Eel Pout		3.°	6.°	
Flounder	42°		3.°	
Dogfish	42°	4.4°	12.°	
Dogfish, young in ovary	42°		20.6°	

Ninety-seven fishes have been observed during the summer, but many of the observations are of doubtful value, as has been explained in the foregoing pages. Such as the experiments are they appear to me to point to the following conclusions:

First. All fishes develope animal heat, its quantity varying according to the organization rather than the habits of the family.

Second. This heat results from the processes of nutrition (chemical) and from the conversion of muscular motion (mechanical). That resulting from the oxidation of the blood is lost in the gills; hence the venous blood is decidedly warmer than the arterial.

Third. Spawning and breeding fishes develope more heat than those not carrying on these processes.

Fourth. Elasmobranchs and, generally, fishes with a highly differentiated digestive apparatus develope more heat than those of simpler organization, and (probably) very active surface fishes more than sluggish bottom fishes.

Fifth. The intestinal canal and arterial blood do not correctly indicate the animal heat of fishes.

Sixth. The question of "normal range of temperature" remains unanswered.

SUGGESTIONS.

Should you think it desirable to continue this investigation I would suggest that the inquiry include the following details, indicated by last summer's experiments:

First. The range of temperature through which living fishes may be carried. This might be observed by subjecting different species in tanks to varying temperatures produced by ice or steam introduced into the water, and noting the body temperature of the fish when it begins to show signs of distress. Each experiment would expend a fish, but the importance and practical bearing of this question of "normal range" of temperature might justify the expense. Much could be learned by observing the temperature of the water at which the fish begins to show signs of distress. In such a harbor as that of Provincetown a considerable difference in the temperature of the water can be got by towing a wooden-latticed tank into shallow water at ebb-tide and into suitable positions at flood-tide.

Second. Amount of oxygen required by different fishes. This may be approximated by keeping different species under observation in separate tanks without a fresh supply of water.

Third. Length of life after being withdrawn from the water, and subsequent duration of muscular irritability. Also the number of respirations per minute in different species when at rest.

Fourth. Influence of muscular movements on temperature. This may be observed by tying a fish by the tail, in the water, until it exhausts itself by struggling, and then taking the temperature, to be compared with an observation upon another individual of the same species under similar circumstances, but at rest.

Fifth. Comparative activity of nutrition as indicated by the percentage of nitrogenous matter in the excreta.

Sixth. The repetition of similar observations on the plan of those made last summer.

TABLE B.

Number of observation.	Date.	Number of instrument.	Depth.	Fish.	Temperature, bottom.	Temperature, surface.	Temperature, air.	Temperature, rectum.	Temperature, circulation.	Remarks.
	1879.				°	°	°	°	°	
1	July 30	5	22 fathoms	Cod	40	69.5		40.7		
2	July 30	5	do	Haddock	40	69.5		42.1		
3	July 30	4	do	do	40	69.5		48		After 10 minutes in warm water.
4	July 30	5	do	do	40	69.5		44.7		
5	July 30	4	Surface	do	40	69.5		58		No. 4, after 15 minutes swimming at surface.
6	July 30	5	22 fathoms	Cod ♂	40	69.5		42.4	44	
7	July 30	5	do	Haddock	40	69.5		40.9		
8	Aug. 2	2	Surface	Blue-fish		73.5		75.6		
9	Aug. 2	2	do	do		73.5		73.3	70	Temperature of circulation from incision in side; vein opened.
10	Aug. 2	2	do	do		73		73.3	72.6	Vein not opened.
11	Aug. 2	2	do	do		73		72.2	71	Incision in side; vein opened.
12	Aug. 4	4	15 fathoms	Dogfish	44.5	70.6		53.2	50.8	After 20 minutes in a tub on deck.
13	Aug. 4	4	Tub	Sea-raven	44.5	70.6		75		Thermometer in stomach. Fish had been ¾ hour in tub at 70.6°.
14	Aug. 6	2	Surface	Blue-fish		70.5		71	72.2	Temperature of circulation from incision in side.
15	Aug. 6	4–5	17 fathoms	Dogfish ♀	40.4	70		49.8	56	Temperature of circulation taken in heart and branchial artery.
16	Aug. 6	4	do	do	40.4	70			57	Do.
17	Aug. 6	4	do	Dogfish, young	40.4	70		61		Young taken from ovary of No. 16.
18	Aug. 11	5	23 fathoms	Cod	42	64.5	69	43.4	44.8	Temperature of circulation from incision in side.
19	Aug. 11	5	do	do	42	64.5	69	43.6	45.8	Temperature of circulation from bloody fluid in thorax.
20	Aug. 11	5	do	do	42	64.5	69	43.6	45.8	Do.
21	Aug. 11	5	do	Dogfish	42	64.5	69	43.8	47.8	Temperature of circulation in heart.
22	Aug. 11	5	do	Pollack	42	64.5	69	44.4	46.5	Temperature of circulation from fluid in thorax.
23	Aug. 11	5	do	Hake ♀	42	64.5	69	44.4	51.8	Temperature of circulation in heart.
24	Aug. 18	[illegible]		Chogset		65.8		67.2		In aquarium; thermometer in stomach by œsophagus.
25	Aug. 18	5		do		66		67		Same specimen as 24.
26	Aug. 25	3	31 fathoms	Eel-pout	43.5			63.2	63.6	After ½ hour in trawl-net.
27	Aug. 25	3	do	do	43.5			62	62.6	Do.
28	Aug. 25	4	do	Goosefish	43.5			50	55.8	Do.
29	Aug. 25	4	do	Skate	43.5			56.6	59.2	Do.
30	Aug. 25	3	do	do	43.5			61.2	62.6	Do.
31	Aug. 25	3	do	Sea-raven	43.5			61.6	64.8	Do.
32	Aug. 25	4	27 fathoms	Skate	43.5			53.2	58.4	Do.
33	Aug. 25	4	do	Goosefish	43.5			52	55	Do.

34	Aug. 28	5	24 fathoms	Dogfish	41.9(?)	61.5	68	42.4	44.4	Taken on trawl-line and nearly drowned when examined. Deep-sea thermometer failed to act on this occasion, and bottom temperature is estimated from the temperatures of the rectum of the fish, and subsequent observations in same locality.
35	Aug. 28	5	do	do	41.9(?)	61.5	68	42.2	45	
36	Aug. 28	5	do	do	41.9(?)	61.5	68	42.4	47	
37	Aug. 28	5	do	do	41.9(?)	61.5	68	....	45.2	
38	Aug. 28	5	do	do	41.9(?)	61.5	68	....	46.8	
39	Aug. 28	5	do	Flounder	41.9(?)	61.5	68	....	44.8	
40	Aug. 28	5	do	Haddock	41.9(?)	61.5	68	....	47	
41	Aug. 28	5	do	Eel-pout	41.9(?)	61.5	68	....	47.9	
42	Aug. 28	5	do	Dogfish	41.9(?)	61.5	68	....	47.3	
43	Aug. 28	5	do	do	41.9(?)	61.5	68	42	44	
44	Aug. 28	5	do	do	41.9(?)	61.5	68	44	....	
45	Aug. 28	5	do	do	41.9(?)	61.5	68	45.7	47	
46	Aug. 28	5	do	do	41.9(?)	61.5	68	44.5	45.9	
47	Aug. 28	5	do	do	41.9(?)	61.5	68	46.5	47.9	
48	Aug. 28	5	do	do	41.9(?)	61.5	68	42.7	48.5	
49	Aug. 28	5	do	do	41.9(?)	61.5	68	45.9	49.7	
50	Sept. 3	3	Near surface	Tinker mackerel	65	68–69	......	69.5	70.1	Taken at 6 feet below surface, temperature at which depth is given as "bottom temperature." Thermometer was inserted into stomach through œsophagus, and into thorax after division of vessels; results are given as "temperature of rectum" and "temperature of circulation."
51	Sept. 3	3	do	do	65	68–69	......	68.1	69.3	
52	Sept. 3	3	do	do	65	68–69	......	68.9	70.1	
53	Sept. 3	3	do	do	65	68–69	......	68.9	70.1	
54	Sept. 3	3	do	do	65	68–69	......	68.9	70.9	
55	Sept. 3	3	do	do	65	68–69	......	69.1	70.9	
56	Sept. 3	3	do	do	65	68–69	......	69.3	70.3	
57	Sept. 3	3	do	do	65	68–69	......	69.3	70.3	
58	Sept. 3	3	do	do	65	68–69	......	69.7	70.1	
59	Sept. 3	3	do	do	65	68–69	......	68.9	....	
60	Sept. 3	3	do	do	65	68–69	......	69.3	70.1	
61	Sept. 3	3	do	do	65	68–69	......	69.3	70.1	
62	Sept. 6	5	15½ fathoms	Dogfish	51.5(?)	64.5	68	45.3	46.9	Muscles of side.
63	Sept. 6	5	do	do	51.5(?)	64.5	68	45.9	51.9	Heart and branchial artery.
64	Sept. 6	5	do	Skate	51.5(?)	64.5	68	....	48.4	
65	Sept. 6	5	do	Dogfish	51.5(?)	64.5	68	46.3	48.7	
66	Sept. 6	5	do	Hake	51.5(?)	64.5	68	45.5	48.5	
67	Sept. 6	5	do	Skate	51.5(?)	64.5	68	45.9	48.3	
68	Sept. 6	5	do	Haddock	51.5(?)	64.5	68	44.4	48.5	
69	Sept. 6	5	do	Dogfish	51.5(?)	64.5	68	....	48.9	
70	Sept. 6	5	do	do	51.5(?)	64.5	68	....	52	
71	Sept. 6	5	do	do	51.5(?)	64.5	68	....	52.9	Taken on ledge, and presumed to have come from a deeper stratum of water of a probable temperature of 44.3°.
72	Sept. 6	5	do	do	51.5(?)	64.5	68	....	51.9	
73	Sept. 6	5	do	do	51.5(?)	64.5	68	....	51.5	
74	Sept. 6	5	do	Skate	51.5(?)	64.5	68	....	49.9	
75	Sept. 6	5	do	Cod	51.5(?)	64.5	68	....	49.1	
76	Sept. 6	5	do	do	51.5(?)	64.5	68	....	50.5	
77	Sept. 6	5	do	Skate	51.5(?)	64.5	68	....	48.5	
78	Sept. 6	5	do	Haddock	51.5(?)	64.5	68	....	50.9	
79	Sept. 6	5	do	Cod	51.5(?)	64.5	68	....	49.9	
80	Sept. 6	5	do	Haddock	51.5(?)	64.5	68	....	52.9	
81	Sept. 6	4	do	Cod	51.5(?)	64.5	68	....	53	
82	Sept. 6	4	do	do	51.5(?)	64.5	68	....	53.2	
83	Sept. 6	4	do	Hake	51.5(?)	64.5	68	51	....	

*Standard.

TABLE B—Continued.

Number of observation.	Date.	Number of instrument.	Depth.	Fish.	Temperature, bottom.	Temperature, surface.	Temperature, air.	Temperature, rectum.	Temperature, circulation.	Remarks.
	1879.				°	°	°	°	°	
84	Sept. 6	4	15½ fathoms	Cod	51.5(?)	64.5	68	50	54.8	Thorax.
85	Sept. 6	5	do	Haddock	51.5(?)	64.5	68	50.5	52.7	Do.
86	Sept. 6	4	do	Cod	51.5(?)	64.5	68	51	55	Do.
87	Sept. 22	3	8 feet	Tinker	60	60	......	....	62	Temperature taken in neighborhood of liver.
88	Sept. 22	3	do	Pollack, young	60	60	......	60.5	63.2	Do.
89	Sept. 22	3	do	Tinker	60	60	......	....	62	Do.
90	Sept. 22	3	do	do	60	60	......	....	63	Do.
91	Sept. 22	3	do	Pollack, young	60	60	......	60.5	63.2	Do.
92	Sept. 22	3	do	do	60	60	......	....	62	Do.
93	Sept. 22	3	do	do	60	60	......	....	63	Do.
94	Sept. 22	3	do	do	60	60	......	....	62.8	Do.
95	Sept. 22	3	do	do	60	60	......	....	63	Do.
96	Sept. 22	3	do	do	60	60	......	....	43.7	Do.
97	Sept. 22	3	do	Sculpin	60	60	......	60.8	63.2	Do.

PREVIOUS INVESTIGATIONS.

Dr. John Davy, in a paper read before the Royal Society, in 1835, on the temperature of some fishes allied to the mackerel, observed that the bonito had a temperature of 90° F. when the surrounding medium was 80.5°; and that it therefore constituted an exception to the generally-received rule that fishes are universally cold-blooded.

*Yarrell says: "The consumption of oxygen, however, is small; and the temperature of the body of fishes that swim near the bottom, and are known to possess but a low degree of respiration, is seldom more than two or three degrees higher than the temperature of the water at its surface." This statement does not appear to be founded upon actual observation, since the temperature of a bottom-feeding fish taken from water at any considerable depth might be, and usually is, much below that of the surface water, and still considerably above the temperature of the water inhabited by the fish. Thus, in the waters about Provincetown, the difference between the bottom and surface water temperatures at 20 fathoms is frequently as great as 30° F. At the time of Yarrell's writing but little was known of the temperature of the water at considerable depths, the deep-sea thermometer being an instrument of comparatively recent use. The quotation illustrates sufficiently well the mistaken theory which underlies the universal belief in the cold-bloodedness of fishes, and which looks to the consumption of oxygen only for the source of animal heat. As has already been shown, whatever heat is developed by this process in fishes is quite lost to its body temperature by the contact of water with the aerated blood in the gills.

The attention of this excellent observer (Yarrell) was strongly attracted to the question of the animal heat of fishes, and he has collected a large number of quotations bearing upon the adaptive power of fishes to extremes of heat and cold, which will be referred to later on. He attached a great deal of importance to the correlation of muscular irritability and "quantity of respiration" in this connection, upon which subject he says: † "Physiologists have shown that the quantity of respiration is inversely as the degree of muscular irritability. It may be considered as a law that those fish which swim near the surface of the water have a higher standard of respiration, a low degree of muscular irritability, great necessity for oxygen, die soon, almost immediately when taken out of the water, and have flesh prone to rapid decomposition. Mackerel, salmon, trout, and herring are examples. On the contrary those fish which live near the bottom of the water have a low standard of respiration, a high degree of muscular irritability and less necessity for oxygen; they sustain life long after they are taken out of the water, and their flesh remains good for several days. Carp, (cod ?), tench, eels, the different sorts of skate, and all the flat fish may be quoted." As against

*History of British Fishes. London, John Van Vorst, 1841. Introduction, p. xx.
†Yarrell, *op. cit.* pp. xv and xvi.

the above statement respecting the speedy death of surface swimmers is the fact observed by myself, that a blue-fish (*Pomatomus saltatrix* (Linn.) Gill), taken August 5, showed distinct signs of life after fifteen minutes spent upon the deck of the yacht, and that a fragment comprising rather more than half the heart continued to pulsate for eight minutes after being separated from the body, and to respond to artificial stimulus for fifteen minutes longer.

Prof. G. Brown Goode, of the Fish Commission, has been engaged for some years in the investigation of the relations of our Atlantic fishes to water temperatures. Last year (1878) he made several direct experiments upon body temperatures, testing the temperature of the rectum with a thermometer and comparing it with that of the water as indicated by a deep-sea (Miller-Casella) thermometer. The experiments were made upon cod and haddock for the most part, and the differences between the rectum of the fish and the water from which it had been taken were found to be inconsiderable, rarely exceeding one degree Fahrenheit, as was the case in the similar experiments made by myself last summer. In the cursory examination which I have made of the literature of the subject I have found no other records of exact experiments upon the animal heat of fishes.

There seems to be, however, no lack of authority for the general belief that these animals are cold-blooded, in the sense that they take on the temperature of the medium which surrounds them, and have not, like the higher vertebrates, a limited normal range of temperature, beyond which life cannot be long sustained. Professor Owen lends the weight of his great name to this opinion (in his general division of vertebrates into *Haematotherma* and *Haematocrya*), and the instances which I now quote of the endurance by fishes of extremes of heat and cold without apparent injury are sufficient to establish incontestably the fact that they do possess such endurance to a remarkable degree. The earlier citations are taken at second-hand from Yarrell (Introduction to History of British Fishes).

*Mr. Jesse (*Gleanings in Natural History*, 2d series, p. 277) tells of a friend who saw a goldfish which had been frozen into a block of ice, and afterwards thawed into life.

*Dr. Richardson relates that the gray sucking carp, common in the fur countries of Arctic America, may be frozen and thawed out again without injury. (*Fauna Boreali Americana*, vol. 3.)

*Perch have been frozen and transported for miles, returning to life when thawed (T. S. Buchanan, *Introduction to the Study of Nature*); and John Hunter says (*Animal Economy*): "that these (fishes) after being frozen still retain so much of life as when thawed to resume their vital actions, is a fact so well attested that we are bound to believe it."

†Mr. J. W. Milner (Assistant Fish Commissioner), had a mud minnow

*Quoted by Yarrell, *loc. cit.*

†Goode *On the Migration of Fishes.* Read before the American Fish Cultural Association, February 28, 1878.

(*Umbra limi* [Kirt.] Günther) which was frozen within solid ice in an aquarium-globe, three or four times, and each time regained its vitality upon being thawed out. Instances similar to the foregoing can be adduced indefinitely.

*The only *hybernation* which is definitely known to occur among fishes, says Professor Goode, takes place in the fresh-water lakes and streams of cold regions. The fishes are driven by cold into the deeper waters, and there remain in a state of torpor, proportional in degree to the amount of cold which they experience. Hybernation does not appear to be in any case a voluntary act. The fishes do not become torpid of their own accord. They avoid it as long as they can, and only succumb when they are deprived of the means of escape. They never become torpid when there are greater depths to which they can retreat.

†Dr. C. C. Abbott reports of the fresh-water mullet (*Myxostoma oblongum*): "No degree of cold seems to affect the movements of this species, and hundreds can frequently be seen under the ice, moving slowly along the bed of the stream, feeding upon the wilted remnants of pond-lily and splatter-dock plants. * * * This applies also to our common roach (*Stilbe americana*), which, to a less extent, braves the chilling waters of our streams throughout the winter, and, in consequence, suffers from the persecutions of the three species of pike (*Esox reticulatus*, *fasciatus*, *porosus*) inhabiting our streams."

‡See also Mr. Rudolph Hessel's observations upon the winter torpor of the carp. This appears to be a true hybernation, during which, although the fish takes no food in some climates from October until March, there is no diminution in weight.

On the other hand, fishes have been reported as living and thriving in water at an exceedingly high temperature; high enough to produce death by coagulation of the albumen in their blood and tissues, unless there is some provision by which their interior parts are maintained at a temperature lower than that of the surrounding water. As the existence of any protection analogous to that afforded to mammals by the function of perspiration and evaporation seems obviously impossible to animals living in the water, it is difficult to understand in what way such a reduction in temperature can be produced and kept up.

§Thus, Humboldt and Bonpland observed living fishes in hot water thrown up from a volcano and showing a temperature of 210° F.

§Desfontaines found a *Chromis* in the hot springs of Cafsa, in Bombay, the water in which showed 30° R. (97.5° F.), and Shaw afterwards saw small mullet and perch in the same springs. (*Travels in Bombay*, folio, Oxon. 1738, p. 231.)

* Goode, *loc. cit.*

† Notes on some Fishes of the Delaware River. United States Fish Commissioner's Report for 1875–76, p. 825.

‡ The Carp and its Culture. Fish Commissioner's Report for 1875–76, p. 869.

§ Quoted by Yarrell, *loc. cit.*

*Saussure saw eels, rotifera, and infusoria in hot springs of Aise, in Saxony, in 1790, at a temperature of 113° F.

*Bruce says that at Feriana, the ancient Thala, are springs of warm water without the town, where he saw small fishes, 4 inches long, not unlike gudgeons. The temperature is not noted, but he says: "Upon trying the heat by the thermometer I remember to have been much surprised that they could have existed, and even not been boiled, by continuing so long in the heat of this medium."

*Facts mentioned by Somerset induced Broussonnet to make some experiments on the degree of heat which river fish are capable of enduring. Details of the degrees of heat are not stated, but many species lived several days in water too hot for the hand. (This and the preceding citation from Dr. Hodgkin's additions to the translation of Dr. W. F. Edwards' work "On the Influence of Physical Agents on Life.")

†Professor Goode writes: "In warm countries an analogous phenomenon (to hybernation) takes place, which has been called *æstivation*. When the lakes and streams are dried up by the heat, the fish seek refuge in the deepest pools, and when they too are dried, they bury themselves in the mud at the bottom and remain torpid until the rainy season refills the reservoirs and revives them."

‡Day reports that on January 18, 1869, he visited a large tank which was then almost dry, having only about four inches of water in the center, while the circumference was hard enough to walk on. The soil was a thick and tenacious bluish clay, from which, fully thirty paces from the water and two feet below the surface, were taken five living fishes. Two were *Ophiocephalus punctatus*, and three were *Rhineobdella aculeata*. They were covered with a thick adherent slime. "*All were lively and not in the least torpid.*" Day also reports *Amphipnous cuckia* as having been dug up under similar circumstances. Mr. Whiting, chief officer of the western province of Ceylon, informed Sir Emerson Tennent that he had been twice present when the peasants had been digging up fish of nine to twelve inches long, full-grown and healthy, which *jumped on the bank* when exposed to the light.

Batrachians, tortoises, and land-snails are commonly found in a torpid state during the hot and dry months, a state which may truly be called *æstivation*, but which differs decidedly from the condition of activity described above as observed in buried fishes, and for which there is no very obvious explanation.

The instances cited are sufficient to show that the popular belief that fishes possess no animal heat of their own rests upon well-attested observations. At first sight it is difficult to understand otherwise how these animals can undergo the extremes of heat and cold which they have been known to undergo and continue to live. Yet, when the adaptability of birds and mammals, whose normal range of body temperature is so extremely narrow compared with that of fishes, to extremes

*Quoted by Yarrell, *loc. cit.* †Goode, *op. cit.*

‡"Fresh Water Fishes of India," p. 28.

of heat and cold is fairly considered, the necessity for this inference seems to be not so very obvious. And no one appears to have tried the experiment of subjecting the *same individuals* to great differences of temperature, whereby the immense effect of inherited adaptation would have been thrown out of the account.

With the exception of the often-quoted paragraph from Humboldt and Bonpland, none of the foregoing observations attest a higher temperature than 113° F., noted by Saussure as endured by eels in the hot springs of Aise. This is but little above the temperature observed at Fort Yuma, in California, which is occupied as a military post.

I have not yet found the original passage from which the statement credited to Humboldt and Bonpland, as to living fish in water at a temperature of 210° Fahr., is quoted. Yarrell gives no indication of the precise place from which he cites. In an essay* "*Sur une nouvelle espèce de pimelodus*" (*P. cyclopum*), however, Humboldt writes: "L'hasard a voulu que ces inondations volcaniques n'eussent pas lieu l'année que j'ai passée dans les Andes de Quito; mais les poissons vomis par les volcans sont un phénomène si commun et si généralement connu de tous les habitans de ce pays, qu'il ne peut pas rester le moindre doute sur son authenticité." From which it appears that, on the occasion referred to at least, he was obliged to rely upon second-hand testimony; especially upon that of M. de Larrea, of Quito, who had collected a cabinet of minerals, was instructed in chemistry, and had looked into the records of many villages around Cotopaxi. From this gentleman he learned that in 1691 myriads of the fishes in question were vomited up from the volcano of Imbabarri, causing a fever among the neighboring people. Some Indians assured him ("quelques Indiéns m'ont assuré") that the fishes were living as they came down the side of the mountain, "*mais ce fait ne me paroit assez avéré.*" Very few of the specimens that he saw were sufficiently disfigured, in his opinien, to indicate exposure to very great heat, and the specimens came out of the mountain mixed with an argillaceous mud. Humboldt conjectures the existence of subterranean lakes whence he supposes the fishes to have come. Not having found the original passage, I cannot, of course, say how far its context might modify the inferences which have been drawn from it as quoted, but it is evident that at the time here referred to, at least, he had no idea that the fishes were alive when thrown out from the mountain, nor did he make any record of the temperature (210° Fahr.) named in the citation.

The instances of frozen fishes thawed into life again differ in kind rather than in degree from familiar experiences with frozen fingers, toes, and ears restored to their integrity by gradual thawing, *when they have not been frozen too long*. In no case, so far as I know, has any attempt been made to ascertain whether the frozen fish retains in its interior parts a temperature above the freezing-point; nor is it stated that

**Recueil d'observations de zoölogie et d'anatomie comparée*, Paris, 1811, tome 1er, p. 22.

fishes have been thawed into life after having been frozen for any great length of time.

* Dr. Richardson's remarks in a recent communication to *Nature*, upon "Suspended Animation," are pertinent to this inquiry. "It is hard to say whether an animal, like a fish, frozen equally through all its structure, is actually dead in the strict sense of the word, seeing that if it be equally and uniformly thawed it may recover from a perfect glacial state. In like manner it may be doubted whether a healthy, warm-blooded animal suddenly and equally frozen through all its parts is dead, although it is not recoverable, because in the very act of trying to restore it some inequality in the direction is almost certain to determine a fatal issue, owing to the transition of some vital centre into the pectous state of colloidal matter. I do not, consequently, see that cold can be of itself and alone utilized for maintaining suspended animation in the larger warm-blooded animals of full growth. * * * It is worthy of note that cold is antiseptic, as though whatever suspended living action, suspended also by some necessity or correlative influence the process of putrefactive decay."

Respectfully submitted.

J. H. KIDDER.

Hon. SPENCER F. BAIRD,
United States Commissioner of Fish and Fisheries, Washington, D. C.

FEBRUARY 10, 1880.

DESCRIPTIONS OF NEW GENERA AND SPECIES OF FISHES FROM THE COAST OF CALIFORNIA.

By W. N. LOCKINGTON.

1. Leurynnis paucidens, gen. et sp. nov.

GENERIC CHARACTERS.—Family *Zoarcidæ*, allied to *Lycodes*. Ventral fins present, short; no teeth on vomer and palatines; dorsal and anal fins continued without interruption around the tail. Scales small, but evident. The name is from *λευρος*—smooth; *ὑννις*—vomer, in allusion to the character which chiefly distinguishes the genus from *Lycodes*.

SPECIFIC CHARACTERS.—Body elongate, eel-like; extremity of snout subtruncate; profile of remainder of snout and head conic, slightly convex over the eyes; highest part of the dorsal outline and deepest part of the fish perpendicular to a point about midway between the posterior end of the lower jaw and the base of the pectoral; from this point to the slightly rounded end of the caudal the body tapers regularly both above and below. Head broad, the sides (viewed from above) almost straight from the opercula to about half-way between the eye and the tip of the snout, thence rapidly approaching and meeting in an obtuse point.

Greatest depth of body from a little more than ten to a little less than eleven times; length of head $4\frac{1}{3}$—$4\frac{2}{3}$ times in the total length; snout $2\frac{13}{16}$

* Quoted from *Forest and Stream*, September 4, 1879.