XXXII.—*On the Temperature of certain Hot-Springs in the Pyrenees.* By
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Having determined to spend my autumn holiday in the Pyrenees, it occurred to me that I might add a link to a very interesting chain of observations which was begun by one of the Vice-Presidents of this Society in the year 1835. Twenty-eight years had elapsed since Principal FORBES made his careful observations of the temperatures of certain of the Pyrenean hot springs; and I thought that if I could repeat his experiments after so long an interval, the results might not be without some interest.*

A visit to the Pyrenees in the year 1835 was so far uncommon as to make a description of the places through which the traveller passed a source of entertainment to the general as well as the scientific reader; but now such description would be tedious. Then, too, some remarks were necessary touching the geological features of the localities where the springs existed; but it is unnecessary to repeat them now, for I am not aware that the explorations into the rocks in search of new springs, or of a more abundant supply of water from the older springs, have altered the relations as described by Principal FORBES. Therefore, respecting the natural aspect of the country, beautiful though it be, and its geological features, I shall have nothing to say; and as I have no new theory of the cause of thermal springs to propound, I need not repeat the speculations with which we are familiar.

The temperature of thermal springs is interesting in a variety of aspects. The geologist and the chemist are alike concerned in it, and to the physician it is a question of no slight importance. In the treatment of diseases by mineral waters, temperature is a cardinal element; indeed in many instances the thermal feature appears to be that by which alone the water is characterised as a medicine. Physicians who frequent the bathing places during the season when invalids resort to them, and who have unusual facilities for witnessing the effects of mineral waters, have great confidence in the curative power of heat. In esti-

* See Principal FORBES' paper "On the Temperatures and Geological Relations of certain Hot Springs, particularly those of the Pyrenees"—*Philosophical Transactions*, Part II. for 1836.

inating the influence of mineral waters three elements are to be considered,—the water itself, the substances dissolved in it, and the temperature. ANGLADA has remarked, that water alone, with the aid of certain temperatures, is capable of producing the diversified effects of a crowd of medicines. Thus, he says, the same liquid which, at a temperature of 35° to 37° Cent. may be used as an emollient, becomes powerfully excitant at from 39° to 41° Cent., and is transformed into an energetic irritant from 42° to 45°,—a temperature which the body can support only for a few seconds (Op. tome ii. p. 381, *et seq.*) M. FONTAN, medical inspector of the waters at Bagnères-de-Luchon, divides the action of thermal mineral waters into two parts; an *immediate* or *physiological* action, due to the temperature of the water, and a *mediate* or *therapeutic* action, due to its mineral ingredients. He remarks that the springs which enjoy the highest and most enduring reputation are those whose temperature approaches nearest to that of the human body, and is constant. He declares, that by means of different temperatures alone he can, by the use of mineral waters, either allay the nervous susceptibility of a Belle, or excite a very Hercules.* M. OURGAUD, the medical inspector of the waters at Ussat, amusingly describes his establishment as a thermal gamut, having a note, that is, a degree of temperature, for every phase of disease.†

But from whatever point of view the subject of the temperature of thermal springs may be regarded, it cannot but be interesting to know whether the temperature be constant or variable.

"It is a singular fact," Principal FORBES remarks, "that we are not only unacquainted with the progressive variations of temperature in springs during long periods of time, but even with the diurnal or monthly changes to which many thermal waters are probably subject. The usual statement of the constancy of the heat of such springs at all seasons is abundantly general, but perfectly vague." This statement, made in 1835, does not seem to have induced any regularity of observations. The same general but unsupported assertions of the constancy of the temperatures, from season to season and year to year, were made to me at

* "Je crois que l'on doit tenir compte avec beaucoup d'exactitude des températures auxquelles on administre les eaux thermales, et je suis persuadé, pour ma part, que les mots *fortes* et *faible*, que l'on prodigue, sans examen, à telle ou telle eau, sont appliqués le plus souvent d'une manière irreflexie quant à la composition de l'eau. Que si l'on entend par forte la propriété *immédiatement* excitante d'une eau thermale, elle doit être bien plutôt entendue de sa température que des proportions chimiques des substances qui y sont contenus. Je me chargerais, pour ma part, de calmer la susceptibilité nerveuse d'une petite-maitresse avec un bain d'eau de la Grotte de Bagnères-de-Luchon—appliqué à + 32 ou + 33 Cent., et d'exciter un Hercule avec la source de la Preste ou du Pré de Cauterets à la température de + 44° et de + 47° Cent."—*Recherches sur les Eaux Minérales*, p. 185.

† "D'où il résulte que ces bains, disposés successivement comme les touches d'un clavecin, offrent une série de températures décroissantes, entre 37 et 31 degrés centigrades, qui forment une sorte de gamme thermale modulée selon les divers besoins de la thérapeutique."—*Précis sur les Eaux Thermo-Minérales d'Ussat-les-Bains*.

most of the thermal stations in the Pyrenees. The utmost that I have met with in the form of a continuous record is contained in work (Eaux Minérales des Pyrénées) by Professor FILHOL of Toulouse. At page 97 of his book, M. FILHOL has given a table of observations made at Bagnères-de-Luchon, at irregular intervals between 1st August 1849 and 15th April 1853; but during that period there are only eighty-six days of observation. It is to be regretted that, from one so highly respected and so eminently fitted to undertake the task, we have not a longer and more connected series of observations. But, far from charging M. FILHOL with lack of zeal, we owe him a large debt of gratitude for the labour which he has bestowed on the subject, and for his very valuable record. The value of the table is enhanced by the facts that the observations are all made by the same person, exactly at the same points of each spring, with the same instruments, they being verified on several occasions. Therefore, as the observer justly remarks, no doubt can attach to his results.

From his laborious personal observations, M. FILHOL is convinced that the temperature of springs—even those best regulated and most protected from water of infiltration—is *not absolutely invariable*. With respect to the variability of their temperature, he divides the springs of Bagnères-de-Luchon into two groups. In the first group he places those springs which do not vary more than a few tenths of a degree at the season of snow-melting, when the level of surface water in the galleries is unusually high; and in the second group those springs whose temperature is more variable, the changes being evidently in relation with the height of the surface water. In the latter group, with a change of temperature, there is generally a corresponding change in the volume of water, a lower temperature being observed with an increase in the abundance of water. But this is not uniformly so. The increase in the volume of water of a spring, at the season of snow-melting, is not always due to water of infiltration. Occasionally the volume of water is increased without any diminution of temperature; more than that, there is sometimes a diminution of temperature with a *diminution* in the volume of water.*

M. FILHOL believes that springs with a high temperature are less susceptible of variations than those of a low temperature.†

* A diminution of temperature does not always follow the increase of surface water: Dr GARIGOU, of Ax, says:—"Plusieurs sources sont, en effet, pénétrées par les eaux pluviales ou par l'eau des torrents à l'époque des fortes crues, et en même temps que leur volume augmente, on peut suivre l'abaissement de leur température et une diminution dans leur richesse en sulfure. Pour deux sources, cependant, j'ai pu, pendant l'hiver, à l'époque de la fonte des neiges, constater une élévation de température bien évidente. Pour l'une de ces sources, celle du Rossignol supérieur, la température s'est élevée de 0·7; et pour la seconde, la source Hardy du Breilh, l'augmentation dans le calorique a été de 1°."—*Etude Chimique et Médicale des Eaux Sulfureuses d'Ax*.

† "Je crois avoir remarqué que les sources les plus chaudes sont celles qui éprouvent le moins de variations; c'est ainsi que la source Bayen a oscillé, dans l'espace de trois ans, entre 67° 25, et 18·10."—*Op. cit.*, p. 96.

M. ERNEST BAUDRIMONT made a series of observations at the *Grande-Grille*, Vichy, to ascertain what changes mineral waters are subject to in their composition from day to day. At the same time he recorded the temperature of the water, and on several days in September 1850, he notes it as follows; showing an extreme range in eleven days of $\cdot 80$ Cent. = $1^{\circ} 44$ Fahr.*

Day of Month	Temperature, Centigrade.	Day of Month.	Temperature, Centigrade.
3	33·33	9	32·80
5	33·33	12	33·25
7	33	14	33·60

Whenever I had an opportunity I put the question, whether the temperature of the springs varied from day to day, from season to season, or from year to year. The answer that I received was almost without exception a negative. When I asked the question of one of my professional brethren, the reply was often a little modified, *trivial* variations being generally admitted; but when I put the question to an *ouvrier* attached to any of the establishments, he invariably betrayed his sense of the importance of uniformity of temperature by a most emphatic denial. The prevailing opinion in the Pyrenees touching the variability of temperature of the springs is precisely what has been stated by Dr LAMBRON, in his comprehensive work (*Les Pyrénées, et Les Eaux Thermales Sulphurées de Bagnères-de-Luchon.*) He says:—"The variations of temperature to which well secured (*bien captées*) thermo-mineral springs are liable are generally so trifling (*de 1 à 2 degrés*), that we may consider the temperature which they bear from the interior of the earth to be constant; and we may attribute the variations to fortuitous causes, operating either in the interior of the globe (as earthquakes), or far more commonly near the surface, as by the infiltration and admixture of surface water. And these variations are so transient, that at the end of a few days, their normal temperature is restored" (p. 414).

Suppose it were commonly admitted, however, that slight variations of temperature do occur from season to season, important as that may be to the physician and his patient, still the larger question, as to a regular and permanent loss or increase of temperature remains to be answered. M. FILHOL remarks, that the changes of temperature are not always in one direction; he found the same springs to be sometimes a little above, sometimes a little below their normal temperature. It is possible, therefore, that temperatures taken at long intervals may differ, to a certain extent, without there being any really permanent change. If one observer record the temperature when the spring is abnormally low, and another when it is abnormally high; or one in winter and another in summer, a difference of several degrees may be obtained, without the water having per-

* *Annales de la Société d'Hydrologie Médicale de Paris*, t. ii. p. 251.

manently changed its temperature, but merely having oscillated between these extremes. One advantage derived from a comparison of my observations with those of Principal FORBES is that we both observed at the same time of year—namely, in or near the month of August.

There are certain circumstances calculated, if not satisfactorily explained, to cast discredit upon the results of an investigation of this kind: they respect the character of the instruments employed; the scrupulosity of the observer; and certain local conditions.

1. *Instruments*.—One of the difficulties that we have to contend with in comparing observations made at long intervals, is that of ascertaining the nature of the instruments employed by former observers. Unless the errors of the instruments are recognised and corrected, it is quite possible that what may appear to be a change of temperature may be nothing more than the fault of a thermometer. Principal FORBES has been most minute in describing the means adopted for the verification of the instruments which he employed; and M. FILHOL has also been at great pains to check the errors of his instruments.

Knowing that accuracy of result depended greatly upon the character of the instruments employed, I applied to one of the first houses in Edinburgh, requesting them to make for me four thermometers of the best description, two going to 140° Fahr., and two to 212° Fahr. These were marked respectively, A, B, C, and D. They were tested by Mr BUCHAN, the acting Secretary of the Scottish Meteorological Society, who having examined them and compared them with the Society's standard thermometers, pronounced three of them perfectly accurate, and the fourth very slightly faulty. The latter was rejected. All the instruments are very sensitive, the mercury rising in the tubes very rapidly when heat is applied. As thermometer D was used at every spring, returned uninjured, and was again tested by Mr BUCHAN and found perfect, I need only describe it. For convenience of carriage, its length is only (from the extreme ends) thirteen inches. It is a simple glass tube without mounting, the scale being marked on the tube, and containing eighteen degrees Fahr. to an inch. The degrees are not subdivided; but I had no difficulty in estimating the parts of a degree.

2. *The Observer*.—Having obtained trustworthy instruments, the next fear of error was from carelessness in using them. Any error from this source I was particularly anxious to avoid, and fearing that—from the awkward positions in which many of the observations were made—I might, in the reading of a figure or otherwise, make a mistake, I always endeavoured to associate myself with some person of local reputation who would accompany me to the springs, and make an observation with his own thermometer at the same time. After the observation at each of the springs was made and entered in my book, the Centigrade degrees of my associate's thermometer were reduced to those of Fahrenheit; if the observations accorded, or were within one or two-tenths of a degree, we

were satisfied; if they differed more than that, we repeated the observations, sometimes three or four times; but often failed in the end to bring the two nearer than within two or three tenths of a degree. Both observations are invariably given in the descriptive remarks and in the tables. When the temperature was taken at a buvette, or other running stream, a large tumbler was placed under the stream; the water was allowed to flow into and over it for a minute or two, until the glass assumed the temperature of the water as nearly as it could be made to do; the thermometers were then placed in the tumbler, and allowed to remain for a short time, and were then read; the water all the time flowing over the tumbler. When the temperature was taken at the *source* (to arrive at which, we usually entered into a gallery or drift, in the floor of which the springs are secured), we dipped our thermometers into the spring, moved them about from place to place to find the hottest part, and read them whilst immersed. When it was practicable, we plunged the thermometers so low as to bring the summit of the mercurial column on a level with the surface of the water, but we could seldom read them in that position, being obliged to raise them a little to bring them to the level of the eye (the head stooping to the floor of the gallery). Sometimes it occurred that the water was so far below the level of the floor of the gallery that we could not get near the thermometers to read them whilst they were immersed. In such cases we got a wine bottle, placed the thermometers in it, tied a cord round its neck, and lowered it into the water. It filled with the water, and we allowed it to remain some minutes, then hauled it up and read the instruments as quickly as possible. Sometimes we were placed in very inconvenient positions, sprawling upon the floor of the gallery, with the head and limbs awkwardly twisted, encumbered with a candle and a thermometer, and exposed to an atmosphere resembling that of a Turkish bath; but we never left a spring without carefully repeating our observations several times when necessary. I most cordially express my thanks to those gentlemen who so patiently accompanied me into these uncomfortable situations, and whose names I shall have occasion to mention hereafter. We often found it very difficult to record an exact temperature when there was an escape of gas from the waters, or where the water rushed up with force. In these cases, the rippling of the water caused the mercury to oscillate in the tube so rapidly, that it was difficult to read the instrument; but we always endeavoured to catch the highest point.

3. *Place of Observation.*—It is difficult to ascertain the exact spot at which a previous observer has plunged his thermometer. So many alterations have been made of late years at the Pyrenean spas, that I scarcely think it likely that I have in many instances succeeded in observing at the precise place occupied by Principal FORBES in 1835. In most instances, my observations have probably been made nearer the actual origin of the springs, because at most of the spas the waters have been traced, by means of excavations, further into the rocks. At

Ax, I believe the position of observation is identical, for no alterations appear to have been made there since 1835; the place answers exactly to Principal FORBES' description. In my remarks respecting each of the places visited, I have endeavoured to mention these local peculiarities.

In describing the points where I have made my observations, I frequently use the word *griffon*. I must explain the meaning of the expression. It is used rather vaguely to express a near approach to the point where the spring emerges from the ground; but I have used it to signify the point where the water passes from the fissures in the rock into the artificial apparatus constructed for its reception, where it is, for the first time, securely cut off from all external influences. This securing of the water is termed *captage*. At this point the water usually issues by several thin streams from the ground, and it is possible that these may have different temperatures. Care is therefore to be taken in immersing the thermometer, to move it about in order to ascertain whether such differences exist. I frequently found that when my companion's thermometer was placed at a little, even two or three inches, distance from my own, different temperatures were recorded. Usually, it is not until the water has become well mixed, at a little distance from the place where it emerges from the rock, that it acquires a uniform temperature.

All my observations were made in the month of August 1863.

EAUX CHAUDES.

Here I had the kind and able assistance of Dr PROSPER DE PIETRA-SANTA, physician to the Emperor, who resides during the bathing season at Eaux Bonnes. He kindly accompanied me to Eaux Chaudes. The thermometer employed by M. PIETRA-SANTA was made, I believe, by FASTRÉ of Paris, and was, as I understood, quite accurate. I measured it with my pocket tape, and found it to contain twenty-five degrees of Centigrade to an inch, or forty-five degrees of Fahrenheit, which on my own thermometer (D) occupy a space equal to two inches and a half.

The thermal establishment which existed in 1835 has since been pulled down, and the waters are now administered in a handsome building, constructed in the years 1848-50 by MM. FRANÇOIS and LATAPIE. The new establishment is built upon the right bank of the Gave, at a distance of only a few yards from the site of the old one. This change of position, however, must necessarily affect the temperature of the water at the place where it is employed by the invalid, the distance between the *buvettes* and the *griffon* of certain of the springs being as much greater now than it was in 1835 as the distance between the old and the new establishments. The effect of this change of position, I was informed, was decidedly injurious to these springs, whose waters are now conducted a greater distance in pipes.

Of the six springs in use at Eaux Chaudes, three are conducted into the establishment, and these are they which are affected by the change of position. They are named *Le Clot*, *L'Esququette*, and *Le Rey*. The other three are employed at the several points at which they rise; they are called *Baudot*, *L'Arressecq*, and *Mainvielle*.

Le Clot.—This spring is received, at its point of emergence, into a reservoir which is hermetically closed. From this reservoir the water is conveyed by two conduits to the establishment—the one leading to the baths, the other to the *buvette*. The water, doubtless, loses a certain quantity of heat during its passage from the actual source to the *buvette*; and I was told, moreover, that, in spite of every effort to preserve it from decomposition, the amount of sulphuret of sodium in the water is much less at the baths and the *buvette* than at the *griffon*. The loss of temperature at the *buvette* I was unable to ascertain, as I had no opportunity of testing it at the *griffon*. The actual temperature observed by me at the *buvette* was 94·00 Fahr. At the same time, M. DE PIETRA-SANTA read his thermometer at 34·50 Cent. = 94·10 Fahr.

L'Esququette.—This spring has been divided into two parts by a recent exploration into the rock; they are termed respectively *hot* and *temperate*. The hot stream is conducted to a *buvette* in the establishment, and supplies also, in combination with the temperate stream, the baths and *douches*. The distance between the *griffon* and the *buvette* of this source, I was told,* is 30 metres, equal to 98·427 English feet. The temperature observed by me at the *griffon* was 93·80 Fahr. M. DE PIETRA-SANTA recorded 34·20 Cent. = 93·56 Fahr. At the *buvette* I found the temperature to be 92·40 Fahr.; M. DE PIETRA-SANTA, 33·50 Cent. = 92·30 Fahr.

Le Rey.—This spring rises on the site of the old establishment, and is immediately received into a reservoir, whence it is conducted to the new establishment. The distance between the *griffon* and the *buvette* I did not ascertain. The temperature recorded by me at the reservoir was 91·40 Fahr., M. DE PIETRA-SANTA at the same time recording 33·00 Cent. = 91·40 Fahr. At the *buvette* I recorded 90·00 Fahr., and M. DE PIETRA-SANTA 32·00 cent. = 89·60 Fahr.

Baudot.—The temperature of this spring was taken at the *buvette*, close to its point of emergence from the granite. My thermometer marked 77·00 Fahr.; M. DE PIETRA-SANTA, 25·00 Cent. = 77·00 Fahr.

L'Arressecq.—The temperature of this spring was also taken at the point where it leaves the granite. My thermometer marked 74·90 Fahr.; M. DE PIETRA-SANTA, 24·00 Cent. = 75·20 Fahr.

Mainvielle.—The temperature of this spring was taken at the *buvette*, which is

* The distances mentioned throughout are such as were told me by the gentlemen who accompanied me to the several springs. I had no opportunity of measuring them.

placed immediately in contact with the *griffon*, or point of emergence, at the foot of a block of granite. The temperature recorded by me was 51·80; M. DE PIETRA-SANTA recorded 11·00 Cent. = 51·80 Fahr.

The following table shows the temperature of the springs at Eaux Chaudes, as recorded by different observers at various periods. I give the Centigrade as well as the Fahrenheit reading of the temperature.

Name of Observer, and Date of Observation.	Le Clot. (Buvette.)		L'Esquirette.				Le Rey.				Baudot. (Griffon.)		L'Arressecq. (Griffon.)		Mainvielle. (Griffon.)	
			(Griffon.)		(Buvette.)		(Griffon.)		(Buvette.)							
	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.
Prof. Forbes (July 1835), .	94·60	34·78	...	...	91·40	33·00	...	...	92·00	33·35	80·20	26·78	76·30	24·62	...	...
M. Fontan (Sept. 1835), .	97·07	36·15	...	...	89·60	32·00	...	...	92·57	33·65	81·05	27·25	77·18	25·10	...	...
M. Fontan (Sept. 1837), .	96·80	36·00	...	...	90·68	32·60	...	...	93·20	34·00	80·78	27·10	77·18	25·10	52·25	11·25
M. Gintrac (1841), . . .	96·80	36·00	...	...	...	...	...	...	93·20	34·00	...	...	...	...	...	...
Professor Filhol (1850), .	93·38	34·10	...	...	...	...	...	...	94·64	34·80	...	...	...	...	...	...
M. Lemonnier (1860), .	97·16	36·20	95·00	35·00	...	...	92·30	33·50	...	...	77·00	25·00	76·64	24·80	52·70	11·50
M. de Pietra-Santa (1863),	94·10	34·50	93·56	34·20	92·30	33·50	91·40	33·00	89·60	32·00	77·00	25·00	75·20	24·00	51·80	11·00
Dr Scoresby-Jackson (1863),	94·00	34·45	93·80	34·33	92·40	33·56	91·40	33·00	90·00	32·22	77·00	25·00	74·90	23·85	51·80	11·00

EAUX BONNES.

At Eaux Bonnes, also, I had the able assistance of M. DE PIETRA-SANTA. There are several springs, but three only were available for my purpose, the rest being mixed in such a manner as to prevent the temperature of each being taken separately. The springs whose temperature I tested were *La Vieille*, *Source du Bois*, ou *Source Froide*, and *Source d'Orteich*.

Both the *griffon* and the *buvette* of *La Vieille Source* are within the thermal establishment, and are within four feet of each other, being separated only by a wall, through which the water is conveyed by a short pipe. At the *griffon*, the temperature was not easily taken. The chamber in which it is situated was gloomy, so that we could not read the thermometers without the aid of a candle; and even with that aid we could not read them whilst immersed in the water, the opening into the spring being very narrow, and the column of mercury, when the bulb was immersed, being below the level of the opening; that is, below the floor of the chamber. Even with my face touching the floor and close to the opening, I could not read the thermometer without raising it several inches, and when I did see the column it was subsiding so rapidly that I could not be certain of having seen it at its highest point. To obviate this difficulty, we placed the thermometers in a wine bottle, which was then lowered into the water, filled, and allowed to remain until the bottle assumed the temperature of the water. It was then withdrawn, and the thermometers were read whilst yet immersed in the water. The temperature recorded by me was 91·20 Fahr.; that by M. DE PIETRA

SANTA, 32·75 cent. = 90·95 Fahr. The temperature was taken also at the *eburette*, and was found to be, as nearly as possible, the same as at the *griffon*.

Source du Bois, or Source Froide.—The temperature of this spring was taken at a little reservoir (about 6 feet by 3) at the point where the water issues from the rock. My thermometer recorded a temperature of 54·80 Fahr., M. DE PIETRA SANTA, 12·80 Cent. = 55·04 Fahr.

Source d'Orteich.—This spring arises in the *Vallée du Valentin*, where an establishment is now building. The temperature was taken at the *burette*, which is placed immediately over the *griffon*, and was recorded by me at 72·30 Fahr., and by M. DE PIETRA-SANTA at 22·50 Cent. = 72·50 Fahr.

The following table shows the temperature of the springs at Eaux Bonnes, as recorded by different observers at various periods:—

Name of Observer and Date of Observation.	La Vieille.		Froide.		Orteich.	
	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.
Professor Forbes (July 1835) . . .	91·40	33·00	54·40	12·45	...	...
M. Fontan (Oct. 1835)	92·03	33·35	55·04	12·80	...	...
M. Fontan (Sept. 1837)	91·96	33·32	55·40	13·00	...	...
M. Gintrac (1841)	91·76	33·20	55·40	13·00	...	...
Professor Filhol (1850)	89·96	32·20	53·96	12·20	...	...
Professor Filhol (1861)	90·95	32·75	55·94	13·30	71·96	22·20
MM. François and Pietra-Santa (1862)	90·95	32·75	55·04	12·80	71·96	22·20
M. de Pietra-Santa (Aug. 1863) . .	90·95	32·75	55·04	12·80	72·50	22·50
Dr Scoresby-Jackson (Aug. 1863) . .	91·20	32·89	54·80	12·67	72·30	22·39

CAUTERETS.

At Cauterets I was kindly received by Dr BURON, and had some conversation with him; but he had been for some time, and was then, suffering from severe illness, and was consequently unable to assist me in my researches. He was good enough, however, to introduce me to his friend Monsieur DE LALANDE, a gentleman who has travelled extensively, and has had great experience in chemistry and engineering; and also to Monsieur BROCA, an experienced pharmacist, who has made himself thoroughly acquainted with the mineral waters of the district. With these gentlemen I spent many hours in observing the temperature of the springs. I employed, as on all occasions, the thermometer marked D. The thermometer employed by MM. DE LALANDE and BROCA was made by SALLERON of Paris, and contained ten degrees of Centigrade to the inch of my measuring tape.

The mineral springs in the vicinity of Cauterets are numerous, and are divided, according to their position relative to the town, into two groups, named respectively *Southern* and *Eastern*. The eastern is the *northern* group of some authors, and occasionally the springs of *La Raillère* are separated into a group by them-

selves, called *Central*. Commonly, however, and sufficiently for our present purpose, they are divided into southern and eastern groups.

Southern Group.

The springs of this group emerge from the granite. We visited them in the following order:—

La Raillère.—The water of this spring is conducted into an establishment constructed at its source. We took the temperature first at the *buvette*, where my thermometer marked 101·30 Fahr., at the same time the thermometer of MM. DE LALANDE and BROCA marked 38·70 Cent.=101·66 Fahr. We then passed to the back of the building and observed the temperature at the *griffon*, which is five and a half metres (=18·044 English feet) from the *buvette*. Here I found the temperature to be 101·80, whilst MM. DE LALANDE and BROCA gave it as 39·00 Cent.=102·20 Fahr.

Mauhourat.—There are two drinking places to this spring,—one at a distance of two metres (= 6·562 English feet) from the *griffon*, and the second at a distance of 260 metres (=853·034 English feet). The *buvette* at the latter point is known as the *Petit Mauhourat*, and was constructed for the convenience of invalids who may find it too fatiguing to go to the principal *buvette* near the *griffon*, the *Petit Mauhourat* being 260 metres nearer Cauterets. The water is conducted from the source to the more distant *buvette* by means of pipes. The temperature recorded by me at the distant *buvette* (*Petit Mauhourat*) was 117·150 Fahr., that by MM. DE LALANDE and BROCA 47·50 Cent.=117·50 Fahr. At the principal *buvette*, near the source, my thermometer marked 121·00 Fahr., that of MM. DE LALANDE and BROCA 49·50=121·10 Fahr.

Les Œufs.—We observed the temperature of this water at three points,—namely, at the *griffon*; at the *buvette* 300 metres (=984·270 English feet) distant from the *griffon* (nearer Cauterets, and in the same building as *Petit Mauhourat*); and again 1400 metres (=4593·259 English feet) below the latter point (or 1700 metres from the *griffon*) at the *Pont de la Raillère*. It is intended to carry the water of *Les Œufs* into Cauterets by means of pipes, the operations for which had been conducted only as far as the *Pont de la Raillère*, hence I had an opportunity of recording the temperature of the water there. The distance still to be accomplished, from the *Pont de la Raillère* to Cauterets, is 1200 metres (=3937·079 English feet). The temperature of the water at the several points of observation was as follows:—

	Thermometer D.	MM. de Lalande and Broca.
Griffon,	131·00 Fahr.	55·00 Cent. = 131·00 Fahr.
Buvette 300 metres from griffon,	128·00 „	53·50 „ = 128·30 „
Escape 1700 metres from griffon,	119·00 „	48·50 „ = 119·30 „

Le Pré.—The temperature of this water was taken at the *buvette*, which is

constructed at a distance of 15 metres (=49 213 English feet) from the *griffon*. The temperature recorded by me was 117·40 Fahr., that by MM. DE LALANDE and BROCA 47·50 Cent.=117·50 Fahr.

Petit St Sauveur.—The temperature of this spring was taken at the *griffon*. I found it to be 93·00 Fahr. MM. DE LALANDE and BROCA recorded 34·00 Cent.=93·20 Fahr.

Eastern Group.

These springs issue from metamorphic schist. We visited them in the following order:—

César.—We observed the temperature of this water at three points,—namely, at the *griffon*; at the *buvette* in the building near the source (distance of this *buvette* from the *griffon* 60 metres =196·854 English feet); and at the *buvette* of the establishment in the town (distance of this *buvette* from the *griffon* 350 metres =1148·350 English feet). The temperature of the water at the several points of observation was as follows:—

	Thermometer D.	MM. de Lalande and Broca.
Griffon,	117·40 Fahr.	47·50 Cent. = 117·50 Fahr.
Buvette near the griffon (60 metres),	116·30 „	47·00 „ = 116·60 „
Buvette at the establishment (350 metres),	114·00 „	45·60 „ = 114·08 „

Espagnols.—The temperature of this spring was observed only at the *griffon*, where I found it to be 115·50 Fahr., and at the same time MM. DE LALANDE and BROCA recorded a temperature of 46·60 Cent.=115·88 Fahr.

Pauze.—The temperature of this water was observed at two points,—at the *griffon*, which is not more than 80 centimetres from the *griffon* of Espagnols; and again at the *buvette*, which is distant 10 metres (=32·809 English feet) from the *griffon*. The temperature recorded was as follows:—

	Thermometer D.	MM. de Lalande and Broca.
Griffon,	109·75 Fahr.	43·25 Cent. = 109·85 Fahr.
Buvette,	102·30 „	39·15 „ = 102·47 „

The following table shows the temperature of the principal springs at Cauterets, as recorded by different observers at various periods:—

Name of Observer, and Date of Observation.	Rallièr. Griffon.		Mauhourat. Buvette of Griffon.		Eufs. Griffon.		Petit St Sauveur. Griffon.		Pauze-Vieux. Griffon.		César. Griffon.	
	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.
M. Arago (1826),	101·12	38·40	121·28	49·60	...	...	...	...	113·00	45·00	117·68	47·60
Professor Forbes (Aug. 1835), .	101·90	38·80	121·70	49·80	130·10	54·50	90·60	32·50	110·30	43·50	118·10	47·80
M. Fontan (Sept. 1835), . . .	102·65	39·25	121·37	49·65	...	...	91·40	33·00	113·00	45·00	118·49	48·05
M. Fontan (Sept. 1837), . . .	...	...	122·00	50·00	...	...	...	...	...	...	...	...
M. Gintrac (1841),	101·30	38·50	122·00	50·00	131·00	55·00	...	...	...	...	118·40	48·00
Professor Filhol (1850), . . .	102·20	39·00	120·20	49·00	131·00	55·00	...	...	...	...	119·30	48·50
MM. de Lalande } (Aug. 1863), and Broca, }	102·20	39·00	121·10	49·50	131·00	55·00	93·20	34·00	109·85	43·25	117·50	47·50
Dr Scoresby-Jackson (Aug. 1863),	101·80	38·78	121·00	49·45	131·00	55·00	93·00	33·90	109·75	43·20	117·40	47·45

ST SAUVEUR.

There are several mineral springs at St Sauveur, but only two of importance, namely, *La Source des Bains*, and *La Hontalade*. As the water of the latter is nearly cold, I did not think it of importance to test the temperature accurately.

Unfortunately, I had not the advantage of a good second thermometer at St Sauveur. M. CHARMASSON DE PUYLAVAL, to whom I was indebted for some attention, showed me a broken thermometer with which he had carefully taken the temperature two years previously. I believe the instrument was made by either SALLERON or FASTRÉ of Paris, and appeared to have been such as that used by MM. DE LALANDE and BROCA at Cauterets.

In company with M. DE PUYLAVAL, I visited the establishment which is supplied with water by the *Source des Bains*. This spring is now isolated from the rest, and has been traced for several yards into the rock, whence it is led by means of a pipe into the establishment.

I tried the temperature at the bath and douche nearest the source (according to M. DE PUYLAVAL, 10 or 12 metres from the actual source). I found the temperature to be 93·50 Fahr. M. DE PUYLAVAL tried the temperature with a common bath thermometer, and found it to be 34·50 Cent. (=94·10 Fahr.) and stated that it corresponded exactly with his previous observation made with the now broken thermometer. I then tested the temperature in the bath-room furthest from the source (about 35 metres distant from the actual source, I was informed), and found it to be 93·00 Fahr. With the bath thermometer, M. PUYLAVAL stated it to be 33·80 Cent. (=92·84 Fahr.), and that it corresponded with his previous observations.

Lastly, I obtained permission to enter into the excavated rock, and tried the temperature at a *robinet*, which I understood was within two metres of the actual source, where I found the temperature to be 94·00 Fahr. M. DE PUYLAVAL had never taken the temperature at that point, and did not accompany me into the gallery.

The observations made by Professor FORBES upon the temperature of the spring which supplies the establishment were not satisfactory. He says,—“ We have stated that there are reservoirs belonging to the thermal establishment of St Sauveur. The consequence is, that the temperature perpetually varies. I have repeatedly tried it at the ‘Buvette.’ Thus on the 20th of July 1835, I found it to be 90·2; and on the 24th, only 88·8.”

The temperature observed at the *Robinet de la Douche* by various observers at different periods is given in the following table:—

	Centigrade.	Fahrenheit.
M. Fontan (September 1835),	34·50	= 94·10
M. Fontan (September 1837),	34·50	= 94·10
M. Gintrac (1841),	34·50	= 94·10
Professor Filhol (1850),	34·20	= 93·56
Dr. Scoresby-Jackson (August 1863),	34·17	= 93·50

BARÈGES.

I visited Barèges after leaving St Sauveur, and on the same day observed the temperature of the springs at both places. At Barèges I had the able and cordial assistance of Dr LE BRET, the medical inspector of the establishment, and well known as one of the editors of the *Dictionnaire Général des Eaux Minérales*. The establishment at Barèges is so constructed that the *griffons* are not approachable. There are no galleries, the water being conducted immediately into the baths, which are built close to the actual sources. The only experiment which I made at Barèges was on the temperature of the *Tambour* (called also *Grande-Douche*). I observed the temperature of this spring at the *Buvette* of the new establishment, the distance, as I understood from Dr LE BRET, between the point of observation and the actual source not exceeding one *metre*. I observed the temperature with thermometer D, and at the same time Dr LE BRET observed it with his own thermometer, which was a much shorter instrument than mine, and the Centigrade degrees were closely marked. The result of our observations was as follows :—

	Fahrenheit.	Centigrade.	Difference (Fahr.)
Thermometer D,	109·10	= 42·83	} 1·20
Dr Le Bret,	110·30	= 43·50	

The difference between our observations could not be reduced by the most careful repetition, and therefore I concluded that the thermometers were at variance. On returning to Dr LE BRET's house, I placed both thermometers in a tumbler of cold spring water, and having allowed them to remain a sufficient length of time, we both examined the instruments with the following result :—

	Fahrenheit.	Centigrade.	Difference (Fahr.)
Thermometer D,	64·40	= 17·83	} 1·20
Dr Le Bret,	65·30	= 18·50	

By this experiment I conclude that our observations at the spring were both correct, and that between the temperatures 18·50 and 43·50 Centigrade, Dr LE BRET's thermometer marks 1·20 Fahr. higher than mine.

Dr LE BRET kindly furnished me with the results of observations made by Professor FILHOL in 1862; they will be found at length in the *Annales de la Société d'Hydrologie Médicale de Paris*, tome neuvième, p. 369. I give them along with others in the following tabular form :—

Name of Observer, and Date of Observation.	Tambour or Grande Douche.				L'Entree.				La Chapelle.				Polard.			
	Buvette.		Robinet of Grande-Douche.		Robinet of Baths.		R. of Cabinet 7.		Robinet of Baths.		R. of Cabinet 1.		Cistern.		Robinet of Baths.	
	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.
M. Arago (1826), . . .	...	...	111.38	44.10	99.87	37.7	...	...	...	...	...	...	...	...	98.78	37.1
Prof. Forbes (July 1835),	...	...	111.9	44.39	104.4	40.22	...	...	88.7	31.50	...	...	97.9	36.61	...	...
M. Fontan (Sept. 1835), .	...	...	112.55	44.75	104.55	40.30	...	...	89.23	31.80	...	...	...	...	99.13	37.30
M. Fontan (Sept. 1837), .	...	...	112.55	44.75	104.72	40.40	...	...	89.15	31.75	...	...	...	...	101.40	38.55
M. Gintrac (1841), . . .	...	...	113.00	45.00	...	...	...	...	87.80	31.00	...	...	...	...	...	...
Professor Filhol (1850), .	...	...	110.48	43.60	...	...	...	...	87.98	31.10	...	...	...	...	...	...
Professor Filhol (1862), .	109.40	43.00	111.38	44.10	...	...	104.00	40.00	...	...	91.40	33.00	...	...	{ 98.60 37.00 Cabinet, No. 12.	
Dr Le Bret (Aug. 1863), .	110.30	43.50	}*	...	...	...	...	...	...	...	...	...	...	...	...	...
Dr Scoresby-Jackson (1863),	109.10	42.83		...	...	...	...	...	...	...	...	...	...	...	...	...

BAGNÈRES-DE-BIGORRE.

At Bagnères-de-Bigorre, I had the kind and able assistance of J. MAXWELL-LYTE, Esq., an Englishman of scientific attainments, who has resided in Bagnères for eleven years. The temperature of the springs was observed very carefully by means of several instruments. I used, as on all occasions, my thermometer D. The instruments employed by Mr LYTE were A, a thermometer made by GREINER of Berlin, and sold in London by HORNE & Co. of Newgate Street. The degrees on this instrument were marked, both in Reaumur and Fahrenheit, forty-five of the latter corresponding to an inch of my pocket tape. B, a thermometer made by FASTRÉ of Paris, with a maximum index; this instrument had twelve Centigrade degrees to the inch of my tape. C, a thermometer (lent for the occasion by M. SOUBERVIE, medical inspector at Bagnères) by FASTRÉ of Paris, having eight degrees to the inch of my tape. Before leaving Mr LYTE'S house, we dipped three of the thermometers (we had not then got M. SOUBERVIE'S instrument) into a large beaker, containing cool spring water. The result was as follows:—

	Fahrenheit.
Thermometer D,	78.40
Greiner's thermometer,	77.50
Maximum,	25.70 Cent.=78.26

In the following remarks, I shall speak only of the temperature as recorded by thermometer D and the maximum thermometer, as there was less difference between them than between the other instruments and mine; but I have kept a record of the temperature afforded by all the instruments.

We first visited the establishment known as *Le Salut*, between six and seven hundred yards from the town. There we observed the temperature of three springs, namely:—

* See explanation of difference in text.

1. *Source de la Montagne*.—The temperature of this spring was taken at its source in a gallery, excavated at a little distance from the building.

2. *Source de l'Interieur*.—Temperature taken at the *buvette* in the building, the distance from that point to the actual source, as I understood, being about one metre.

3. *Source de la Pompe*.—Temperature taken at the *buvette* in the building, being, as I understood, close to the griffon.

The temperature of the three springs was as follows :—

	Thermometer D.	Maximum.
Source de la Montagne, . . .	89·00 Fahr.	31·60 Cent. = 88·88 Fahr.
La Buvette de l'Interieur, . . .	87·80 „	30·90 „ = 87·62 „
Source de la Pompe, . . .	87·00 „	30·40 „ = 86·72 „

Afterwards, accompanied by a workman to remove the coverings, we visited the sources of the springs which supply the principal establishment situated in the town. We visited the springs in the following order :—

1. *Source du Platane*.—At this spring we could easily read the thermometers whilst immersed in the water.

2. *Source du Foulon*.—Here the water was too far below the floor of the gallery to permit of our reading the thermometers accurately whilst in the water. We therefore placed the instruments in a quart bottle, which was lowered by means of a cord into the water, filled, and allowed to remain several minutes. It was then raised, and the thermometers were immediately read before their removal from the bottle.

3. *Source du Dauphin*.—At this spring we could readily read the instruments whilst immersed in the water.

4. *Source de la Reine*.—The approach to this spring is not so easy as to the others. We were able to read the instruments distinctly whilst immersed in the water. We also took the temperature of the water of La Reine at the *buvette* in the establishment; the distance between the latter point and the actual source where we had previously observed it, being, as I understood, about 100 metres (328 English feet).

5. *Source de Salies*.—This spring rises in the open space, about twenty paces from the right-hand corner of the establishment (the observer looking at the front of the building). At present the spring is open, half a dozen steps leading down to it; but it is proposed to extend a wing of the establishment over it.

The temperatures observed were as follows :—

	Thermometer D.	Maximum.
Source du Platane, . . .	92·30 Fahr.	33·40 Cent. = 92·12 Fahr.
Source du Foulon, . . .	95·00 „	35·00 „ = 95·00 „
Source du Dauphin, . . .	119·40 „	48·40 „ = 119·12 „
Source de la Reine (<i>griffon</i>), . . .	115·00 „	46·00 „ = 114·80 „
„ „ (<i>buvette</i>), . . .	110·40 „	43·50 „ = 110·30 „
Source de Salies, . . .	123·00 „	50·45 „ = 122·81 „

The following table shows the temperature of several of the springs at Bag-nères-de-Bigorre, as recorded by various observers at different periods :—

Name of Observer and Date of Observation.	Foulon.				Dauphin.				La Reine.						Salies.	
	Griffon.		Bath.		Griffon.		Conduit.		Griffon.		Conduit.		Buvette.		Griffon.	
	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.
M. Arago (1826),	...	...	...	...	...	...	...	...	114·80	46·00	...	...	...	...	122·90	50·5
Prof. Forbes (Aug. 1835), .	...	...	93·20	34·00	...	...	119·0	48·33	...	...	114·0	45·6	...	...	...	...
M. Fontan (Oct. 1836), . .	...	...	{ 95·54 35·30 } { Robinet. }		122·00	50·00	...	...	115·88	46·60	...	...	...	...	125·24	51·80
M. Fontan (Sept. 1837) , .	...	...	94·10	34·50	118·94	48·30	...	...	115·70	46·50	...	...	...	...	123·98	51·10
Professor Filhol (1861), . .	95·90	35·50	...	...	119·75	48·75	...	...	115·70	46·50	...	...	...	...	123·44	50·80
F. Maxwell-Lyte, Esq. (1863),	95·00	35·00	...	...	119·12	48·40	...	...	114·80	46·00	...	...	110·30	43·50	122·81	50·45
Dr Scoresby-Jackson (1863),	95·00	35·00	...	...	119·40	48·55	...	...	115·00	46·11	...	...	110·40	43·55	123·00	50·55

BAGNÈRES-DE-LUCHON.

I spent several hours in the galleries at Luchon, and observed the temperature of many, but not of all, the springs. My notes of the temperatures are before me now, but I scarcely think they are calculated to fulfil the present object of determining whether the temperature of these springs be constant or not. So much engineering skill has been spent upon the excavations at Luchon that I suppose Principal FORBES, who visited the place in 1835, would scarcely recognise the places where he dipped his thermometers; and, as still further exploration is determined upon, probably in a short time the places where I made my observations will be obliterated. Another reason why I am not anxious to publish my observations made at Luchon is, that I had no second thermometer whereby to check the reading of my own. Unfortunately Dr LAMBRON, from whom I received much attention and kindness, had left his thermometer in Paris; and M. FONTAN, the talented inspector, from whom I also received much kindness, had in like manner left his thermometer at his winter residence. I was accompanied into the galleries by an intelligent workman, who afforded me all the assistance in his power; but I am not sure that he clearly apprehended my questions, though he never failed to make a very spirited reply. For the temperatures of the springs I must refer to the works of M. FONTAN, Dr LAMBRON, and M. FILHOL.

I spent a short time at the baths of Ussat (Ariège), and noted the temperature of the springs. I was kindly aided by Dr OURGAUD, the medical inspector, in whose work will be found a notice of the temperature, and of other matters of interest connected with the mineral water.

AX ARIÈGE.

For determining the question of the variation of the temperature of mineral

There is therefore a difference of half a degree of Fahrenheit between our observations in the one case, and of nearly the same amount in the other. I remember that Dr GARRIGOU explained to me that the difference was probably due to a slight alteration in his thermometer. I made a note of his remark at the time, but have mislaid it, and I can scarcely venture to repeat it from memory.

But whilst, on the one hand, Ax is one of the best places for testing the constancy of the temperature of hot springs, because of the locality not having undergone any material change; still, on the other hand, perhaps but little dependence can be placed upon the results, in consequence of the exposure of the water in its course to many external influences. Dr GARRIGOU has noticed that the temperature of most of the springs at Ax varies with the season, and he adds: *Il n'est pas étonnant qu'à Ax, où les sources sont mal captées, au milieu d'alluvions, et dans le voisinage de plusieurs rivières, on ait observé des variations fréquentes dans les indications fournies par le thermomètre.*

The following table shows the temperatures recorded by various observers at different periods:—

Name of Observer and Date of Observation.	Canons. Taps.		Rossignol. Griffon.	
	Fahr.	Cent.	Fahr.	Cent.
M. Pilhes (1786),	168·98	76·10	...	...
Professor Forbes (1835),	168·0	75·6	161·2	71·8
M. Fontan (1835),	168·26	75·70	166·12	74·50
M. Gintrac (1841),	167·00	75·00	163·40	73·00
M. Roux (1842),	168·26	75·50	166·12	74·50
Professor Filhol (1853),	167·72	75·40	171·50	77·50
Dr Garrigou (1861, summer),	167·36	75·20	170·96	77·20
Dr Garrigou (1862, winter),	167·72	75·40	172·04	77·80
Dr Garrigou (1863, August),	166·64	74·80	171·50	77·50
Dr Scoresby-Jackson (1863, August),	166·20	74·55	171·00	77·22

From these observations it would appear that whilst there is, perhaps, in no instance a permanent change of temperature, neither is there in any an undeviating temperature. It is probable that the temperatures of these springs in the interior of the globe have undergone no change, and that the changes observable upon the earth's surface are due to superficial and evanescent causes,—such as external temperature, the infiltration of cold surface-water, and the like. To a certain extent, an allowance must be made for inaccuracies; for it is scarcely to be supposed that all the observers dipped their thermometers exactly at the same points, nor do I know that, in all cases, errors of instruments were recognised and corrected.