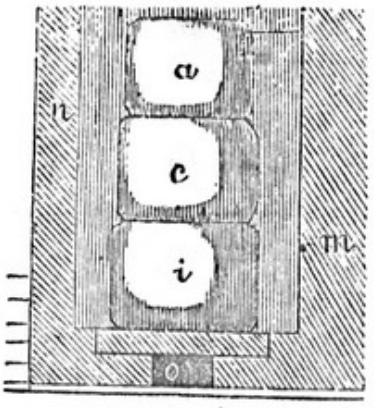
the action of the fuel; and the bars at the bottom were of brass, on which bricks were placed to support the pumice-stone for the reception of the charcoal. The introduction of this brazier into the tepidarium shows the force of prejudice in favour of the common mode of warming by a pan of charcoal. In the caldarium a much higher temperature was necessary than in the tepidarium, and this was obtained from the hypocaust and hot wall, without the room being filled with the fumes of charcoal; a comfort that might also have been enjoyed in the tepidarium by means of the flue formed under the pavement. It is not quite certain, however, that the suffocating vapour was at all times excluded from the caldarium itself, notwithstanding its great surface of hot floor and hot wall, that under modern management would have sufficed not only to "diaphorise, but to bake the Pompeians." Gell observed a stone in its floor that was moveable, and was probably placed there to be occasionally lifted to permit a current of hot air from the hypocaust to enter the caldarium.*

The form and proportions of the caldrons that heated the water for the bath are given in Fig. VIII. from the impression very visibly remaining in the bed of the mortar in which they had been fixed. The caldrons were arranged one above another, and set in a kind of oven, without flues running round them, and were named, like the chambers, according to their temperature and use; the lowest, next the fire, *i*, was called the caldarium; the next, *c*, was the tepidarium; and *a*, the upper caldron, was the frigidarium: *m* is the wall of the bath; and *n*, a wall enclosing the boilers; *o*, the flue of the furnace. By means of a syphon, when boiling water was drawn off from the caldron of boiling water, *i*, it was

* Gell. Pompeiana, ii. vol. i. p. 120.

refilled with warm water from the middle one, *c*; and this vessel in its turn was replenished with colder water from the uppermost boiler, *a*, into which cold water flowed from the cistern.*

FIG. VIII.



The matrice or bed of one column only of caldrons was found; but, as it was seldom necessary to have more than one fire in the baths to warm both the rooms, and the water; it is thought that three columns of boilers (nine vessels) were placed over the same fire in one oven.†

Where a large quantity of water was wanted, heating it in boilers on this plan, would appear to be nearly impracticable; and the magnificent baths at Rome, it has been conjectured, were heated in another manner.

A series of hypocausts was constructed after the method described by Vitruvius; and similar to the stove under the caldarium in the baths at Pompeii. Upon these stoves ranges of substantial vaulted stuccoed water tight chambers were built one above the other, into the walls of which were inserted earthen pipes, that communicated with the hypocausts beneath.

The vaulted roof of the tier of chambers was formed into a shallow reservoir, that was left open to the air; and into this cistern the water from the public aqueduct was conducted to have its temperature raised as much as possible, by exposure to the sun, before it was allowed to fall into the water chambers beneath it.

* Gell. Pompeiana, vol. i. pl. xxv.
† Ibid. ii. vol. i. p. 129.

If both ranges of chambers, and the reservoir forming their roof, be supposed filled with water, and fires made in the hypocausts, the floors of the lower range of chambers will be heated, and the smoke rising through the earthen pipes from the hypocausts heating the walls, the water contained in these lower chambers will have its temperature raised also. This will then communicate heat to the floor of the second tier of chambers, and warm the water standing on it. The operation is the same as that of the caldron apparatus. As the hot water from the lower range of chambers is drawn off for the supply of the baths, the tepid water in the second range descends and replaces it; and, at the same time, the water that has been slightly warmed by exposure to the sun in the shallow reservoir on the roof, falls into the tepid water chambers.

FIG. IX.

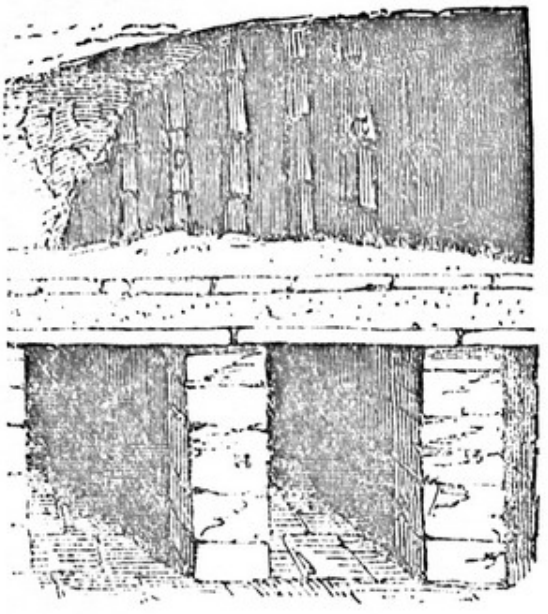


FIG. X.

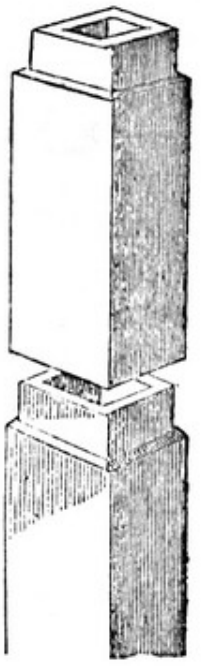


Figure IX. is a section of a portion of one of the hypocausts. B B, the piers; A, the floor of the hot water

chamber. The way in which the pipes were placed in the walls, is seen at c, a part where the stucco had fallen down, when Piranesi made his sketch from which the figure was taken.*

One variety of the earthen pipes that were built into the walls is represented in Figure X. They were about 1¾ inches thick, and fitted into each other with a sort of spigot and faucet joint that lapped about 2 inches. Another sort was cone-shaped, and, when placed in the wall, the narrow end of the one was inserted about 2½ inches into the wide end of the other. Some were made cylindrical, others were parallelopipedons, and, when used in the building, their ends were merely placed in contact. The drains that conducted underground the hot water from one part of the bath to another, were sometimes formed of these earthen pipes cased with bricks; and to prevent the water being cooled as it flowed through them, the drain or conduit was surrounded by a flue, that led from and communicated with the hypocaust, or, when it had one, with its furnace. They were thus enclosed in the centre of a hot funnel, and could by this means be heated before the water entered, and have their temperature preserved, while it was running from the caldrons.

In some ancient baths that stood where is now the church of St. Cecilia in Trastevere, the same end was attained by another method. To diminish the dispersion of heat by radiation, the copper tubes that served for flues or pipes were gilt at those parts where they were exposed to the atmosphere.†

Cameron, who considers the method of heating water in chambers of masonry to be feasible, gives some illustrations drawn from the remains of the baths of Caracalla. In these magnificent *thermæ*, he

* Cameron. Baths of the Romans.
† Ibid. p. 36.

states, there are twenty-eight chambers placed in two rows, of fourteen on a side, built over a hypocaust. Each chamber being constructed, as he expresses it, "on the principle of Papin's digester," about 49 feet 6 inches long, 27 feet 6 inches wide, and about 30 feet high, will contain 40,837 cubic feet of water spread over 1,361 feet of floor, heated by the hypocaust beneath it. The whole heating surface will, therefore, be 19056 feet, having 1,143,450 feet of water standing on it, to have its temperature raised, on an average, 35° in summer, and 52° in winter; and to be kept at this heat for three hours, together with the thick walls and floors of the water chambers, and the pillars and walls of the hypocausts. When we take into account this immense mass of wall, pavement, and fluid to be heated by wood fires made under floors, varying in thickness from 13 to 20 inches, composed of such imperfect conductors as tiles and cement, and extending over a surface of 19,056 feet; and if we reflect also on the defective construction of the heating chamber, and the enormous waste that this alone must have occasioned of a scarce and expensive fuel, the greater part of which had to be brought from Africa;* the certain practical difficulties attached to the plan will appear so great, that it is probable the hypocausts in these baths were intended only to preserve the temperature that was given to the water contained in the chambers above them by some other apparatus, with which, however, the moderns are unacquainted.

That contrivance is conjectured to be alluded to by Seneca, when he speaks of *dracones*, or small thin brass pipes made in a winding or serpentine form, and placed in a fire, so that water entering cold at one end of the pipe or *draco*, from its convolutions through

* Symmachi Epist. l. 10. ep. 58.

the furnace issues boiling at the other extremity; by which means, as the water could be made to boil in a vessel not connected with the fireplace, a bath could be heated in any situation. In some cases a *milarium* formed part of the heating apparatus. What this was is uncertain. Some interpret the term to express a combination of caldrons like that described in a preceding page;* while others consider it to designate a kind of reservoir connected in a certain manner with the coiled pipe or draco.

According to this guess, which, whether correct or erroneous, gives us a glimpse of a most ingenious invention, the milarium was a leaden vessel of considerable dimensions, containing water. In the middle of this reservoir was a furnace that had its bottom and sides formed of brass. The dracones, or thin brass pipes winding round the inside of this furnace, were enveloped by the flames. One end of the draco was inserted into the milarium near its bottom, and the other near its top. The water entering at the lower orifice was discharged hot from its upper end, and the entire mass in the milarium was heated by this circulation in the draco.

Thermæ of a large dimension might have had several milaria connected with them, but those of moderate capacity, and more especially private baths, were probably sufficiently supplied with one. Its great value to the Romans arose from the facility it gave of heating elevated or hanging baths. In these structures it was a principal object not only to have them as large and commodious as those placed on the ground, but to insure an extensive prospect to the bathers. The milarium put this in their power. The draco could be carried from a furnace below to any

* Baccius. De Thermis, p. 443.

height, and it was a more manageable and compact apparatus than a hypocaust, if erected on an upper floor.

A figure of the draco copied from an ancient painting, agrees nearly with the preceding description,* and a diagram of it given by Castel a century ago seems to have been the type of a meritorious modern revival of the ancient apparatus.†

The ignorance of a salubrious and effective system of warming apartments among the Romans, is well exemplified by the solicitude shown by the younger Pliny, to turn to profitable account a source of heat that is neglected in modern buildings, as one which no ingenuity could make adequate to the lowest want of domestic comfort.

The villa Laurentinum was situated on the sea coast, about seventeen miles from Rome, and although not extensive, it was large enough to afford every desirable accommodation. From the station, and taste of its owner, and being built for habitation during the winter months, it most likely contained all the conveniences for heat and ventilation that were to be found in the houses of men of the highest rank in Rome.

From a plain porch, says Pliny, you enter a portico of the form of the letter O, which includes a small but agreeable area. This affords a pleasant retreat in bad weather; as it is not only enclosed with windows, but sheltered by an extraordinary projection of the roof. From the middle of the portico you pass into a handsome hall, that has folding doors and windows on every side. On the left of this apartment lies a large drawing-room, and beyond that a second of a smaller size, having one window to the rising and another to

* Cameron. Baths of the Romans, p. 42.
† Castel. Villas of the Anc. p. 56.

the setting sun. The angle that the projection of the hall forms with this drawing-room, retains and adds force to the heat of the sun. To this warm corner, continues Pliny, my family resort in winter to perform their exercises; for, sheltered from all winds, except those which are generally attended with clouds, nothing renders this spot useless but what, at the same time, destroys the fair weather. Contiguous to this is a room that juts out and forms the segment of a circle; the windows of which are placed so as to receive the sun the whole day.* From hence you pass into a bedchamber, through a passage which, being boarded and suspended, as it were, over a hypocaust beneath, tempers the heat which is emitted, and conveys it to all parts of the bedchamber.

In the opposite wing is a room ornamented in a very elegant taste; adjoining is another room that, though large for a parlour, makes but a moderate sized dining-room. It is exceedingly warmed and enlightened, not only by the direct rays of the sun, but also by their reflection from the sea. Beyond is a bedchamber with its ante-room; its height renders it cool in summer, and being sheltered on all sides from the wind makes it warm in winter. To this a similar apartment is joined by a party wall. From thence you enter into a handsome and spacious cooling room belonging to the bath, contiguous to which

* A room constructed in this form, and for the same purpose, was discovered at Pompeii.

"The *cubiculum*, with the bow window, was doubtless the principal one in the villa; having the ends towards the country circular, it continued to receive the full influence of the sun from the dawn to the close of the day. When the shutters were closed, light was admitted by bull's-eyes over the windows. The alcove in the middle of the chamber was enclosed by a curtain. On one side is a recess hollowed out of the solid construction. This was probably the toilette, as it contained several vases which apparently had contained perfumes and unguents."—Donaldson. Pompeii Illustrated, vol. ii. p. 30.

is the perfuming room, then the sweating room, and next to that the furnace which conveys heat to the bath; adjoining are two small elegantly fitted up bathing-rooms, and next to them is a warm bath, wherein one may swim, and at the same time have a prospect of the sea. Near it is the tennis-court, that lies open to the warmth of the afternoon sun. From thence you ascend a sort of turret, containing two entire apartments below, as there are the same number above, besides a dining-room, which commands very extensive prospects. At the other end is a second turret, in which is a room that receives the rising and setting sun. Behind this is a large repository, and near it a gallery of curiosities; and underneath a spacious dining-room, where the breaking of the waves is heard but faintly. From the banqueting-house in the garden an enclosed portico extends, which has a range of windows on each side; but on that which looks towards the sea, they double in number those next the garden. These are all thrown open when the weather is fair and serene; but if it blows, those on the side the wind sets from are shut, while the other remains open without inconvenience.* The portico itself is coolest when the sun is most scorching, that is, when its rays fall most directly upon its roof. By setting open the windows, the western breezes have a free draught, and prevent the enclosed air from stagnating. At the upper end of the portico stands a detached building, which I call my favourite. It contains a very warm winter room, one side of which looks upon the terrace. The other has a view of the

* Ventilating by opposite apertures seems to have been well understood. Varro, De Re Rustica, l. i. c. 5, tells us how several cities in Greece were preserved by Hippocrates during a pestilence, and of great cures done by himself in a parallel case at Coreyra, by no other knowledge than that of rightly disposing the apertures of the houses.

sea; and both lie exposed to the sun. Adjoining this is a bed-chamber, which neither the voice of the servants, the murmuring of the sea, nor even the roaring of the tempest, nor lightning, nor the day itself, can penetrate, unless you open all the windows. Annexed to this is a small hypocaust, from which, by opening a little aperture, the heat is let out to warm the bed-chamber to the degree required, and beyond this lie an ante-chamber and chamber that also enjoy the sun, though obliquely, from the time it rises till the afternoon.*

Thus far Pliny, who, it is manifest, made warmth a principal consideration in the construction of his villa, and delighting in warm apartments, took all opportunities to have the benefit of the sun both within doors and abroad, as much and as long as possible. To enjoy his beams the whole day, he formed one end of his dining-room like that curve which he thought the glorious luminary made in his course round the world, and when obliged to make projections in his building, he contrived them so as to form a warm corner for his family to take exercise in, since no fires were made in the house, except in the kitchen, and in his own apartments. His sleeping-room was placed to have the benefit of the morning sun; and to remedy the inconvenience of its being situated in a cold corner in the winter, he warmed it from a hypocaust under a small room adjoining, as being more convenient for a servant on the outside of the chamber, to admit what heat was necessary, without disturbing the person that was asleep, than if it had been made under it. He shows no care to heat any other room in this winter villa, except his bed-room in the garden-house, as if he chose rather to keep himself warm by

* Ep. l. ii. ep. 17.

additional clothing, or by exercise, or by retiring to those rooms which were warm by their position, than by the heat of a hypocaust. Our ignorance of ancient manners, and deep-rooted prejudices imbibed during that period of our lives when we generally read the classics, have taught us to think very highly of Roman magnificence, and luxurious enjoyment; but, in this instance, Pliny himself admits that real comfort could only be found in his little bedchamber in the pleasure-house in the garden, a room that would now be considered most dismal in the winter by a modern domestic, for its small window was closed with wooden shutters only.

It may here be observed, that, in general, the arrangement of a Roman house was such that the sun could shine through the *compluvium* or the opening in the roof of the *atrium* or hall; and being commonly only one story high, and rarely exceeding two, it must have been warmer and drier than houses of the present day, that preserve something of the ancient form, but where the court is usually darkened and rendered damp and chilly by the greater height of the surrounding buildings. In town houses, however, the rooms must have been very gloomy, as the only light they could receive entered through an aperture in or over the door, and even this light was often borrowed. Under these circumstances the ventilation must have been most imperfect; and in spite of their use of talc, glass, and linen shutters, and of curtains, carpets, and braziers, still the want of fires generally, and chimneys entirely, must have reduced the ancient inhabitants of Italy, as it does the modern population, to endure, under additional clothing, that state of discomfort and cold damp which is always produced whenever the sky is overcast between November and April. Yet no people are

more sensible of the slightest variation of temperature than the Italians; and none make a more plentiful use of warm clothing. They also know the use of chimneys; but popular as well as professional prejudice prevents their introduction; and people who follow the rules of their physicians, *avoid* them, and live in rooms warmed by pans of burning charcoal set on the middle of the floor, or under the table at which they sit, without a funnel of any sort to carry their fumes out of the apartment,—but such has been the custom in Italy from the most ancient times.

In the cold and changeable climate of Britain, the Romans adopted a more economical and healthful method. Almost all the remains of their houses that have been discovered, show that the means of heating them by hypocausts and flues were provided at the erection of the building, not for one or two rooms only, as in Pliny's Laurentine villa, but for every apartment designed for habitation by the family.*

These hypocausts are of two kinds. The first con-

* The hypocaust at Withington was 27 feet 6 inches in length, and 19 feet wide. The piers were formed of brick, 8 inches square, and the average distance between the piers was 14 inches.—Archæologia, vol. xviii. p. 112.

At Caerleon, the piers were built of circular bricks, 14 inches in diameter, "piled on each other like cheeses."—Roy. Military Antiq. p. 197. Arch. vol. ii. p. 6.

The pillars of the hypocaust at Wroxeter were formed of fragments of columns of granite that had before been used for some other purpose, 14 inches diameter. There was much irregularity both in the distance and placing of the pillars. In the same villa two other hypocausts had pillars 8 inches square, 2 feet distant from centre to centre.—Phil. Trans. No. 306. Arch. vol. ix. p. 326.

The hypocaust at Cirencester was 32 feet long, by 24 feet wide, and had pillars 8 inches square, with tiles for bases and capitals, 11 inches square, on which rested tiles 2 feet square, and on them others of the same size to receive cement for floor; pillars 2 feet 3 inches asunder. —Arch. vol. vii. p. 407. A plan and sections of this hypocaust are given in Carter's Ancient Architecture, p. 7.

Roman house at Rodmarton. Piers of the hypocaust were 21 inches high, and 8½ inches square; spaces between the piers from 7 to 10 inches. They were of brick, and the mortar joints were ½ of an inch in thickness.—Arch. vol. xviii. p. 115.

In the remains of a Roman building on the river Esk, five out of the seven rooms had hypocausts under them, constructed in the

structed with flues running under the floor of an apartment, and heated from a fireplace made on the outside of the building; and the second kind formed like a low chamber, having its ceiling supported by small pillars as described by Vitruvius, or by dwarf walls, and sometimes having flues leading from them under other apartments. The hypocaust discovered at Lincoln will explain this variety, of which Figure XI. is a ground plan, and Figure XII. is a section. The same letters on both Figures refer to the same part.*

The hypocaust was 24 feet 6 inches long, and 9 feet 6 inches wide. It contained four rows of brick pillars, *a*, *a*, *c*, *c*, two of which were square, and two circular. The square pillars, *a*, *a*, were 8 inches on the side, and about 9 inches apart; the circular props, *c*, *c*, were 11 inches in diameter. Each pillar had a projecting brick or tile about 11 inches square for its base, and another tile of the same size that formed a capital, making its height, and that of the heating chamber, about 26 inches. Large bricks, *e*, *e*, varying from 16 to 20 inches square, and 2 inches thick, were laid on the pillars to form the ceiling of the hypocaust. On these were placed courses of tiles, bedded in mortar, and on them a layer of stucco, to form the floor of the room, *z*, to be heated; the entire thickness of the floor being about 10 inches. The fire-hearth was at *i*; and the flame and smoke

usual manner with flues, and heated from the outside.—Roy. Mil. Antiq. pl. 46. King. Munimenta Antiqua, vol. ii. p. 182.

In the Villa Rustica, adjoining the villa at Bathorne End, the flues of the hypocaust were 18 inches deep, and 14 inches wide. At the extremity of every flue, within 3 or 4 inches of the top, a brick funnel was placed in the wall.—Rooke. Arch. vol. ix. p. 205.

Hypocaust at Chester. Had thirty-two pillars, 2 feet 10½ inches high, 18 inches distant from each other, standing on a mortar floor, spread on the rock.—Pennant. Tour in Wales, p. 2.

At Dover, the pillars of a hypocaust were 20 inches high, 9 inches square, and 15 inches apart.—Archt. vol. v. p. 327.

The pillars in an ancient bath at Lipari were 2 feet high.—Arch. vol. xxiii. p. 100.

* Vetusta Monumenta, vol. i. pl. 47.