Medical History, 1979, 23: 191–214.

"CURES WITHOUT CARE"[1] "CHYMICAL PHYSICIANS" AND MINERAL WATERS IN SEVENTEENTH-CENTURY ENGLISH MEDICINE

by

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AFTER A LONG period of decline during the Middle Ages, interest in the healing properties of mineral waters revived in England in the last quarter of the sixteenth century. The warm springs at Bath and Buxton were already regaining their popularity for bathing by 1570, especially for rheumatism, gout, and skin diseases.[2] The baths were also considered to increase fertility, but the *drinking* of mineral waters for medicinal purposes was not then common and only slowly gained ground. Traditional medicine was generally opposed to the use of these waters, especially for drinking ". . . which is very adventurously and most dangerously practised against both reason and all authority."[3] However, as it became known that they were sometimes effective against gravel and bladder stone as well as gout, the search for new springs was intensified and the vogue for spa treatments developed. For the physician, the existence of a mineral spring in his locality could be a most lucrative aid to his medical practice. The earliest known work to discuss in English the curative properties of mineral waters and so make the information more widely available was published in 1562,[4] but from then on works on the medicinal virtues of these springs began to appear in increasing numbers as mineral water treatments were more frequently recommended by English physicians. In such books a topographical account of the position of each spring with reference to the surrounding countryside and especially the nature of rock formations nearby, would be followed by a description of the

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[1] This phrase is borrowed from Michael Stanhope, op. cit., note 9 below.

[2] Both were known in Roman times, and interest had revived about 1570. John Jones (fl.1570–80), *The benefit of the ancient bathes of Buckstones which cureth most grievous sicknesses, never before published*, London, 1572; also, *The bathes of Bathe Ayde*, London, 1572.

[3] Tobias Whitaker, Περι Ταροποεισε *or a discourse of waters. Their qualities and effects diateticall, pathologicall and pharmacaiticall*, London, 1634, p. 101. Whitaker's reference was to the practice of drinking the waters of a newly discovered mineral spring near Norwich ". . . by pottles at one time and in the morning cold and fasting . . . contrary to the practice of all that ever were rationall . . .". Ibid., p. 106. The book was recommended by William Clement, Registrar of the Royal College of Physicians, *Phil. Trans. R. Soc. Lond.*, 1669, 4: 1038ff. For Clement, see W. Munk, *The roll of the Royal College of Physicians*, 3 vols., London, Royal College of Physicians, 1878, vol. 1, p. 146.

[4] William Turner (Dean of Wells), *A booke of the natures and properties as well of the bathes in England as of other Bathes in Germanye and Italye etc.*, London, 1568. Turner's work first appeared as a brief essay on English baths appended to a book on the medicinal virtues of English plants in 1562. C. Webster, *The great instauration*, London, Duckworth, 1975, p. 298.

nature and properties of the water, its action on the body, and recommendations about its use as a medicine.[5]

A more general account of the origins, chemical contents, and medicinal properties of English mineral waters was published in 1631 by Edward Jorden, physician at Bath. Friend of Libavius, Jorden adopted the iatrochemical tradition of Paracelsus and Van Helmont and was amongst the earliest of the "chymical physicians" in this country. The book went out of print after two editions, but was later revived by Thomas Guidott in 1669, who summarized Jorden's classification of minerals in a table (Fig. 1).[6] Jorden was a pioneer of chemical analysis and his book became a standard for many later seventeenth-century physicians who followed his lead.

A NATURAL MEDICINE

The healing properties of most mineral springs were discovered accidentally by local inhabitants who had received some benefit attributed to their use, and it was easy to believe that those who could speak from experience knew the powers of the waters better than the physician himself, however learned. Older springs still retained their traditional Christian connexions as Holy Wells, whilst their chemical contents, as of those more recently discovered, were unknown.[7] Claims for the healing properties of the waters were frequently such as to constitute an almost universal remedy. For instance, it was said of the waters of St. Peter's Well, near Edinburgh, that ". . . being impregnate with this . . . naturall medicine, it bursts out dauncing bringing with it *the cure of all diseases*."[8] Michael Stanhope, a contemporary of Jorden, writing about the Knaresborough springs in 1632, extolled their virtues against palsy, migraine, ulcers of the kidney, the stone, melancholy, digestive troubles, "flixes,

[5] Examples of such seventeenth-century works include: William Barclay, *Callirhoe, the nymph of Aberdene, resuscitat by W. Barclay. . . . What diseases may be cured by drinking of the well at Aberdene, and what is the true use thereof,* Edinburgh, 1615 (reprinted Aberdeen, 1670 and 1799). Tobias Venner, *Via recta ad vitam longam, or a plaine philosophical discourse of the nature . . . and effects of all such things, as by way of nourishments and diateticall observations make for the preservation of health . . . wherein also . . . the true use of our famous bathes of Bathe is . . . demonstrated,* London, 1620 (2nd ed., enl., 1622; later eds., 1628, 1637, 1638, 1650, etc.). Edmund Deane, *Spandacrene Anglica: or the English Spaw fountaine in the Forest of Knaresborow,* York and London, 1626, (later eds., 1649, 1654, 1736); reprinted with introduction by J. Rutherford, and biographical notes by Alex Butler, Bristol and London, Wright, 1922; 1st ed., reprinted, Norwood, N. J., W. J. Johnson, 1974. Tobias Venner, *The bathes of Bathe . . . also . . . A censure of the water of St. Vincent's Rock near Bristol,* London, 1628. Ludowick Rowzee, *The Queen's Welles, that is a treatise of the nature and virtues of Tunbridge Water etc.,* London, 1632 (2nd ed., 1671).

[6] Edward Jorden (1569–1632), *A discourse of natural bathes and mineral waters wherein the original of fountains in general is declared. The nature and difference of minerals, with examples of particular bathes etc.,* London, 1631 (2nd ed., 1632, dedicated to Francis, Baron Cottington); 1st ed., reprinted New York, Da Capo, 1971. Biographical material on Jorden in Munk, op. cit., note 3 above, vol. 1, pp. 113–114; Jorden, op. cit., 3rd ed., London, 1669, edited by Thos Guidott, preface; Thos. Guidott, *A century of observations, containing further discoveries of the nature of the hot waters at Bathe,* London, 1676, pp. 166–167.

[7] For example, Thomas Guidott, *A true and exact account of Sadler's Wells etc.,* 1684, traces the origins of this spring to a much older Holy Well. Guidott makes no attempt to investigate the chemistry of the spring.

[8] A. M.[oor], *The discovery of St. Peter's Well, at Peterhead in Scotland . . . shewing the admirable virtues thereof, against many deplorable diseases,* Edinburgh, 1636 [no pagination], (my italics).

FIGURE 1

A table of minerals with their qualities

(Adapted from Edward Jorden, *A discourse of natural bathes . . .*, 3rd ed., London 1669, edited by Thomas Guidott.)

- **Minerals are either**
  - **1. Earthly**
    - Simple, Dry, Cold, Astringent.
    - or mixed with
      - Nitre — Fuller's Earth, Marle — Abstergent
      - Allum, Copperas — All sorts of "Boles", Astringent and Desiccative.
      - Bitumen — Turfe, Peate etc. — Fat and Unctuous
  - **2. Stone**
  - **3. Bitumina**
    - Solid
      - Terra Ampelis
      - Succinum
      - Gagates
      - Ambra
      - Camphora — Borneo, China
      - Tithantrax
    - Liquid
      - Petroleum
      - Naphtha

      — Potentially Hot and Dry in the 2nd or 3rd Degree; Except Camphir, concerning the Nature and Qualities of which Authors disagree.
  - **4. Concrete Juyces**
    - Salt — Astringent, Detergent, Purging, etc.
    - Nitre
      - Sal Ammoniacum
      - Borax
      - Altincar
    - Allum, Vitriol — Very astringent and cold
  - **5. Spirits**
    - Quicksilver; Various in its Qualities
    - Sulphur; Moderately Hot and Dry, and somewhat Cooling
    - Arsenic
      - Auripigmentum
      - Risagulum
      - Sandaracha
      - Rusma, etc.

      — Venomous, Extremely Hot and putrefying
    - Cadmia[21]
      - Natural, Liquid, Dangerous and a strong corrosive
      - Factitious, Moderately Hot and cleansing
  - **6. Mean or Half Metals as**
    - Bismutum or Tin-glass: Qualities not mentioned
    - Antimony purgeth violently
    - Bell-metal, not used in Physick
  - **7. Metals**
    - Perfect
      - Gold, Qualities uncertain
      - Silver, Esteemed Cold, Dry, Astringent, Emollient
    - Imperfect
      - Hard
        - Iron, Opening and Astringent
        - Copper, Temperate in heat, less Astringent and more cleansing than iron
      - Soft
        - Tin, Cold and Dry, yet moving sweat
        - Lead, Cold and Dry

https://doi.org/10.1017/S0025727300051371 Published online by Cambridge University Press

calthars and obstructions", worms, epilepsy, asthma, and, as if this were not enough, went on to say,

> These and what not that Art could ever cure,
> Nature presents them with a water pure;
> Which fitly us'd in its due season can,
> Restore a dying to a living man.[9]

Stanhope, though not himself a physician, claimed some medical authority at second hand by basing his book on the work of Edmund Deane, the famous York physician.[10]

Some doctors themselves, however, made over-ambitious claims for the healing powers of medicinal springs. This may well be explained in part by the growing enthusiasm for chemical medicines, especially amongst younger physicians. Most of those who advocated the internal use of mineral waters belonged, like Jorden, to the Helmontians whose philosophy of chemistry provided ample grounds for believing in the power of the waters to correct chemical imbalances in the body.[11] Fermentation, central to the generation of minerals in the earth as to the digestion of food, provided for the Helmontians a link between the formation of mineral waters and their action as medicines. This led to chemical theories about these waters in parallel with iatrochemical theories of digestion. In 1687, Patrick Madan, physician at Tunbridge Wells, spoke of the "able, worthy and eminent" physicians there, who, ". . . by their diligent Scrutiny into the Recesses of Nature, are come of late years to great Perfection and Knowledge of Physick here in England, far excelling those of former Ages wherein Physick laboured under a dying Hippocratical Face . . .".[12] Yet, though Madan claimed the Tunbridge Wells chalybeate to be effective in a very wide range of diseases, he was well aware that the expected relief did not invariably follow the use of mineral waters. In order to protect the reputation of the physicians, he transferred any blame for failure to the patients, for, ". . . if you take 'em in the left hand, or by the wrong handle, they can cause thousands of diseases, and hasten even death itself."[13]

[9] Michael Stanhope, *Cures without care. Or a summons to all such who finde little or no helpe by the use of ordinary physick to repaire to the Northern Spaw. Wherein . . . it is evidenced to the world, that infirmities in their owne nature desperate and of long continuance have received perfect recovery, by vertue of minerall waters neare Knaresborow . . . etc.*, London, 1632. This first appeared as *Newes out of York-Shire: or an account of a journey in the true discovery of a sovereigne minerall medicinal water . . . near . . . Knaresbrough, not inferiour to the Spa in Germany*, by M. S.[tanhope], 1626.

[10] See note 5 above. Deane acknowledged Stanhope's work in his editions of 1649 and 1654; in the 1736 edition "Dr. Stanhope" is mentioned in error.

[11] For discussions of the Paracelsian/Helmontian-Galenist controversies amongst physicians in the 1660s, see, for example, H. Thomas, in E. Ashworth Underwood (editor), *Science, medicine and history. Essays . . . written in honour of Charles Singer*, 2 vols., London, Oxford University Press, 1953, vol. 1, pp. 56–71. R. P. Multauf, *Bull. Hist. Med.*, 1954, **28**: 101–126; 1955, **29**: 154–163. A. G. Debus, in F. N. L. Poynter (editor), *Chemistry in the service of medicine*, London, Pitman Medical Publishing Co., 1963, pp. 5–26. P. M. Rattansi, *Ambix*, 1964, **12**: 1–23. A. G. Debus, *The English Paracelsians*, London, Oldbourne, 1965, pp. 137–174. C. Webster, *Ambix*, 1967, **14**: 16–41; *Bull. Hist. Med.*, 1967, **41**: 393–412. L. S. King, in A. G. Debus (editor), *Medicine in seventeenth century England*, Berkeley, Los Angeles, and London, University of California Press, 1974, pp. 7–31.

[12] Patrick Madan, *A philosophical and medicinal essay on the waters of Tunbridge etc.*, London, 1687, p. 20. In his reference to the "Hippocratical face" of medicine, Madan clearly intended to criticize the Galenists.

[13] Ibid., p. 2.

TERRESTRIAL CHEMISTRY AND THE ORIGINS OF SPRINGS

In the *Natural bathes*[6] Jorden claimed that English spas, although not so widely known, were as good as any of the more popular foreign ones. After remarking on the ancient uses of public baths and on the relatively slight references to mineral waters in ancient authors, he brushed all this aside and in the new experimental tradition asserted that he himself had much more accurate information to offer, based on studies of these waters at first hand. By definition he said, mineral waters were ". . . such as besides their own simple nature, have received and imbibed some other qualitie or substance from subterranean mynes."[14] He was aware that by "simple nature" he was referring not to the metaphysical element water, but to natural water "free from heterogeneal admixture", which could be identified by its colour, taste, smell, and other properties such as "thinness" and "levity". He knew that there were usually several dissolved or suspended substances in most mineral waters and that both hot and cold waters were known.

As for the origins of mineral waters, Jorden followed the Helmontian argument that they came from the sea.[15] Sea water was thought to percolate down through fissures and crevices in the rocks, picking up minerals and salts as it went, before reappearing at the surface again. This ancient theory was also accepted by some other physicians. Madan accounted for the formation of the Tunbridge Wells chalybeate in a colourful Hermetic description of an imaginary process within the Earth. "Venus comes from the salt Sea through many Crannies, Interstices, Pores of the Earth, and dangerous Precipices foaming to meet her beloved Mars in the Bowels of the Earth: Who she no sooner embraces, but she is impregnated and big with a Valiant Hero, in the Bed of Honour with no insip'd delight: From thence soon after this Congression, she rises Tryumphing in our Hemisphere at Tunbridge . . .".[16] One practical problem for this theory was the fact that many springs were known to rise in high ground, well above sea-level. This was solved neatly by John French using the concept of distillation caused by the internal heat of the Earth, followed by condensation as the water vapour came into contact with cooler rocks and air near the Earth's surface.[17] The fact that this would produce pure water was passed over.

Explanations of natural processes in terms of laboratory operations were common among exponents of the so-called "spagyrical art". This supported the view that the art of the chemist was an excellent imitator of Nature. Matthew Mackaille, an Edinburgh physician, listed thirteen such laboratory processes with their natural equivalents.[18] (Fig. 2).

Metals and minerals, thought to originate from seeds in the same way as do plants and animals, were continually being generated within the Earth by fermentation

[14] Jorden, op. cit., note 6 above, p. 8.

[15] Helmont's authority was Ecclesiasticus. J. R. Partington, *A history of chemistry*, 4 vols., London, Macmillan, 1961–64, vol. 2, p. 228.

[16] Madan, op. cit., note 12 above, p. 7.

[17] John French, *The Yorkshire Spaw, or a treatise of four famous medicinal wells . . . near Knaresbrough in Yorkshire etc.*, London, 1652, pp. 10f.

[18] Matthew Mackaille, *Moffet-Well; or a topographicall-spagyricall description of the mineral wells at Moffet . . . translated and . . . enlarged by the author etc.*, Edinburgh, 1664 (1st Latin ed., 1659). As a Helmontian Mackaille says, "The knowledge of fermentation is the key of Nature, which the Former of all things, hath put into the hands of man . . .". Ibid., p. 30.

FIGURE 2.
Equivalence between chemical laboratory operations and natural processes
(Adapted from Matthew Mackaile, *Moffet-Well . . .*, Edinburgh, 1664.)

	"Spagyrical" operation	Natural equivalent
1.	Distillation	Vapours elevated to the second region of the air (cold as the head of a still), condense and fall as drops.
2.	Sublimation	As of snow.
3.	Crystallization	As of *Sal Gemma*, ice and hail.
4.	Coagulation	Of sea-salt by heat of Sun.
5.	Calcination	Of horse-bones (and other animals which die in the field) by Solar rays.
6.	Filtration	Of water through veins of the Earth, "for it is most limpide which cometh out of fountains".
7.	Dulcification	Of Sea-water, "whilst it passeth through the bowels of the Earth."
8.	Circulation	Of Salino-sulphureous spirits in the superfice of the Sea. Transmutation of elements is also circulation.
9.	Salification	As of nitre in caves and vaults
10.	Fermentation	"Which doth always precede generation: For there is no corruption without an antecedent fermentation."
11.	Solution of minerals	By water impregnated with some corrosive salt.
12.	Conflagration	Of thunder.
13.	Aurification	In the veins of the Earth, "which many Spagyricks have in vain, engaged to imitat [*sic*] upon its superfice".

processes.[19] Underground streams were therefore likely to come into contact with partly formed masses of minerals in which the sulphureous and mercurial elements had not yet fully united. The concept was sometimes elaborated in the fullest detail as the following description of the formation of the water of St. Peter's Well shows.

> Within the earth from whence our Petrean water flows, is a concavite, a great vessel . . . wherein is contained *materia proxima metallorum* which sends forth its tincture with our water . . . here

[19] Jorden, op. cit., note 6 above, p. 80. For detailed discussions of Jorden's theories of the generation of metals, see A. G. Debus, 'Edward Jorden and the fermentation of the metals', in Cecil J. Schneer (editor), *Toward a history of geology*, Cambridge, Mass., Massachusetts Institute of Technology Press, 1969, pp. 100–121; also A. G. Debus, *The chemical philosophy*, 2 vols., New York, Science History Publications, 1977, vol. 2, pp. 344–357.

> as yet the matter is not coagulate, neither is mercurie united to its salt and sulfur; but nature finding the salt, sulfur, and mercurie of minerals, as yet not united, conjoyns them by digestion and cohobation, sublimating and subtilizing the earthly part, rendering the mercurial fixed, going on naturally with all the operations requisite to the perfection of the work, as coagulation, cibation, sublimation, fermentation, exhaltation, augmentation . . ..[20]

Of the six metals (gold, silver, copper, iron, tin, and lead), iron was known to be most commonly found in mineral waters, and Jorden mentioned the chalybeate springs at Tunbridge Wells and St. Vincent's Rock near Bristol. There were in addition the "mineral spirits"; readily volatilized substances amongst which Jorden identified mercury, sulphur, arsenic, bismuth, antimony, and "cadmia" (see Fig. 1).[21] The poisonous mercury was occasionally found in mineral waters, but neither arsenic nor bismuth were known to occur, though antimony, a violent purge, had been found in a few springs.

The water flowing in underground streams might contain one or more of the "concrete juices" of which the best known was vitriol, formed by ferments acting upon the vapours of sulphur within the Earth. "There ariseth a sulphureous exhalation by the action of the subterranean heat: Which mixed with water makes a sharp corrosive juyce, proper to corrode and drink up a part of copper and yron . . . which we call vitriol."[22] Vitriol was sometimes identified with an "Essurine Acid Salt", a universal salt which could take on different forms according to the minerals with which it came into contact: "As water impregnate with this Acid runneth through the subterraneal Channels and meeteth with a glebe of Alum, Nitre, Marcasites of Iron or of Copper, etc., so it is determined to this or that Specifick Salt, whether Alum, Nitre, *Sal Gemma,* Vitriol of Iron or Copper . . .".[23]

The "concrete juices", having extracted tinctures and spirits from minerals, imparted peculiar properties to the water, the most obvious being its distinctive taste.[24] Although these partly formed minerals were dissolved in the water, the procesess by which the minerals were being formed in the Earth continued in the solution and might not even be complete by the time the water issued from the Earth.[25] This raised

[20] A. M.[oor], op. cit., note 8 above.

[21] "Cadmia"—a general term describing a variety of products, mostly compounds of zinc. Some were waste products of furnace operations, others were found naturally. Agricola, *De re metallica* (1556), translated by H. C. Hoover and L. H. Hoover, London, Mining Magazine, 1912; reprinted, New York, Dover Publications, 1950, pp. 112–113 (n. 8), 403, 539, 542. Partington, op. cit., note 15 above, vol. 2, pp. 49, 59, 108. Libavius, *Alchemia,* 1597, identified cadmia with calamine; Partington, op. cit., p. 168.

[22] A. M.[oor], op.cit., note 8 above.

[23] Samuel Derham, *Hydrologia philosophica, or an account of Ilmington Water in Warwickshire; with directions for drinking of the same. Together with some experimental observations touching the original of compound bodies,* Oxford, 1685, p. 41. French, op. cit., note 17 above, says "Vitriol . . . is but an essurine acid Salt . . .", p. 54; Timothy Byfield (op. cit., note 59 below), makes the same point ". . . there is a certain Hermaphroditicall Salt of Metals . . . called an Essurine or Acid Salt . . . accommodated to all Metals . . .". p. 21.

[24] Agricola identified six kinds of tastes in spring waters, viz., salty, nitrous, aluminous, vitroline, sulphurous, and bituminous. *De re metallica,* Dover ed., op. cit., note 21 above, p. 34.

[25] D. Foot, *Phil. Trans. R. Soc. Lond.,* 1669, 4: 1055, wrote, ". . . from the moment of the sulphur and Acide Salt's meeting and contact begins a mutual action and reaction upon one another which never ceaseth; till both are imperceptibly spent and blended into a new body which then the water lets fall, and we call an Earth, Ochre or Sediment . . . But this mutual action and reaction may last, till

the question whether the medicinal effects of these waters might not depend upon such continuing reactions, and leant strong support to the belief that to obtain the full curative effect it was necessary to visit the spring and drink the water at its source.

MINERAL-WATER CHEMISTRY AND MEDICINE

In order to identify the dissolved minerals, Jorden strongly advocated the examination of their crystals—a procedure which he knew could indicate not only the identity of the substance, but also its degree of purity. "For example, if salt-peeter be brought to you to examine whether it be perfect good or not, dissolve it in water, and set it to shoot [i.e. crystallize] in a wooden dish; and if it shoots in needles . . . it is right: But if any of it shoot in squares or angles, or lumps, it is mixt and unfit either for medicine or Gunpowder."[26] Saltpetre was known to occur quite widely in the soil of farmyards for example, where it was continually regenerated. Alum was also known to occur widely; Jorden mentioned deposits at Oakengates in Shropshire, used by dyers at Shrewsbury; in Yorkshire, Wales, and at Armagh in Ireland. He recognized the similarity between alum and the vitriols and suggested that the latter might be alum with a tincture of iron or copper.[27]

Another way of identifying these minerals, apart from crystallization, was by precipitation, ". . . whereby those mineral substances are striken down from their concrete juices which held them, by addition of some opposite substance. And this is of two sorts: either salts as tartar, soap-ashes, kelps, urine, etc. Or sour juices as vinegar, lemons, oyle of vitriol, sulphur, etc. In which I have observed that the salts are proper to blew colours, and the other to red . . .".[28] Jorden clearly wished to establish experimental criteria for determining what substances the waters contained. He was aware, however, that there were real practical difficulties involved, especially in quantitative measurements. Helmont had used the specific weight of water samples as a criterion of purity, and others had followed him, but Jorden pointed out that the difference in weight between one sample of water and another was so small as to be, ". . . hardly discerned by the ballance, both because simple waters do very little differ in this point, and also because many mixt waters, if they be only infected with spirits, and not corporeal substances, retain the same proportion of heaviness with simple water; and also because it is hard to have great ballances so exact, as a small difference may be discerned by them . . .".[29]

Turning to the medicinal properties of mineral waters, Jorden placed more emphasis on traditional ideas (see Fig. 1). Taking the four primary qualities to apply to these waters, he accepted the view that they derived a special drying quality from their origins in the Earth. The proportions of the primary qualities in different waters led

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the waters issue out of the Earth, and for some small time longer, and so long their Medicinall vertues are to be imparted and no longer . . .".

[26] Jorden, op. cit., note 6 above, p. 45. Saltpetre was an item of national concern at this time, Webster, op. cit., note 4 above, pp. 377–380. It is likely that Jorden had often been asked to pronounce on the purity of such specimens.

[27] Jorden, op. cit., note 6 above, p. 44f.

[28] Ibid., p. 146. This was an early reference to the use of acid-base indicators, Debus, *Chemical philosophy*, op. cit., note 19 above, vol. 2, p. 351.

[29] Jorden, op. cit., note 6 above, p. 15.

to secondary qualities by which they were held to be penetrating, astringent, opening, resolving, attracting, mollifying, cleansing, and so on. Cooling waters, containing nitre, were valuable for hot distempers of the liver, stomach, kidneys, bladder, etc., whilst heating water containing vitriol, were good for certain stomach disorders, "cold distillations", palsies, and so on. Cleansing waters were used for internal ulcers, mollifying waters for hard and schirrous tumours, and astringent waters for all kinds of fluxes. Jorden held that great benefit could be obtained by drinking mineral waters in the correct way and he was even prepared to recommend patients to drink the Bath water, providing care was taken to ensure that it was not contaminated from the bath itself. Given that assurance, "I should not doubt to commend them inwardly to heat, dry, mollify, discuss, glutinate, dissolve, open obstructions, cleanse the kidneys and bladder, ease cholicks, comfort the matrix, mitigate fits of the mother, help barrenness . . .".[30]

If as a chemist Jorden was something of a pioneer, in his medicine he remained much more within the traditional modes of explanation, relying heavily on the four primary principles and the balance between them, rather than the sulphur, mercury, and salt of the chemists.

There was one problem about mineral waters which became apparent as soon as chemical analysis was applied to them. Most seemed to be so dilute that very large doses were often thought necessary in order to accomplish the cure. John Peter, a physician at Lewisham in south London, describing a spring discovered there about 1648, mentioned the usual comprehensive list of diseases for which the water was to be used and gave details of the cure which was to last twenty days.[31] On the first day the patient was told to drink three pints of the water. This quantity was then to be steadily increased day by day, rising to eight and a half pints on the tenth day. Thereafter the amounts were to be steadily decreased until the patient took three pints again on the last day of the treatment. Samuel Derham, an Oxford physician, similarly ordered patients to take the Ilmington mineral water each day for a month, beginning with three pints on the first day and increasing daily by one pint up to eight pints. This quantity was then to be taken each day for about two weeks, after which the doses were steadily reduced to the end of the month.[32] This approach recognized only a need to take into the body a sufficient quantity of the chemical constituents of the mineral waters, ignoring any special qualities they might possess. It reduced the attractiveness of the waters for many patients, and some later physicians made efforts to overcome the difficulty by extracting the salts themselves and offering them for sale in crystalline form.

CONTROVERSY OVER "SCARBROUGH SPAW"

Although it was chiefly amongst the younger physicians that the chemical study of mineral waters developed, some older colleagues also advocated their use whilst

[30] Ibid., p. 150. Colic, a common complaint in the seventeenth and eighteenth centuries, was often due to lead poisoning.

[31] John Peter, *A treatise of Lewisham (but vulgarly called Dulwich) Wells in Kent, shewing the time and manner of their discovery, the mineralls with which they are impregnated, etc.*, London, 1680.

[32] Derham, op. cit., note 23 above.

interpreting their contents and medicinal value in more traditional terms. An interesting case of the contrast between the two approaches occurred in York between 1667 and 1680 when Robert Wittie and William Simpson argued about Scarborough Spa. The controversy had its origins in the contemporary quarrels between Helmontians and Galenists in the Royal College of Physicians[33] and it illustrates the use which could be made by ordinary provincial physicians of the contending medical theories of their time. It seems certain that Simpson hoped to discredit his rival so as to attract patients away from him.[34]

Robert Wittie, whilst practising medicine at Hull, first became aware of Scarborough Spa in 1641 (it had been discovered by a local gentleman about 1627), and thereafter took note of all the cases which came to his attention in which it proved successful. In 1651 he moved to York where he soon established a large and fashionable practice, and nine years later he published a small treatise on Scarborough Spa, partly, it seems, to celebrate the return of the king. In 1667 he issued a second, enlarged edition in which he discussed the origins and nature of different kinds of natural waters, including mineral waters.[35]

In describing the Scarborough mineral water, Wittie claimed five principles, viz., nitre, alum, vitriol, iron, and salt. Five quarts of the water on evaporation yielded one ounce of an ash-coloured sediment, the chalybeate part of which was also found to be deposited when the water was transported, particularly if oaken casks were used. The water then lost its curative properties. To give an account of the five principles Wittie went back, as Jorden had done, to the origins of minerals and metals in the Earth, where, ". . . as they are subject to corruption in time, by reason of many impurities . . . so they have need to be repaired and preserved by generation, as Dr. Jorden observes."[36]

Wittie mentioned four ways by which minerals and metals may be imbibed by water. First, the water might receive the vapour of a metal or mineral as shown by the taste of metal in water which has stood for some time in a metal pan. Second, water could imbibe minerals by taking up their "juices" whilst they are still young and fiery. Third, there was Galen's suggestion that water containing dissolved vitriol would corrode the mineral and so dissolve it, and fourth, minerals might actually change into water, as salt, nitre, and even alum do when a small quantity of water is added to them.

As to the notion that mineral waters originate from the sea, Wittie was distinctly dubious. ". . . the manner of conveyance of the sea-water to the heads of Springs

[33] See note 11 above.

[34] F. N. L. Poynter, in Underwood (editor), op. cit., note 11 above, vol. 2, pp. 72–81. For Wittie, see Munk, op. cit., note 3 above, vol. 1, pp. 413–414; J. Venn and J. A. Venn, *Alumni Cantabrigiensis*, Part I (to 1751), 4 vols., Cambridge University Press, 1922, vol. 4, p. 446. For Simpson, see ibid., p. 81; R. W. Innes Smith, *English-speaking students of medicine at Leyden*, Edinburgh, Oliver & Boyd, 1932, p. 213. Neither is in the *Dictionary of national biography*.

[35] Robert Wittie, *Scarbrough Spaw: or a description of its nature and virtues*, York, 1660; *Scarbrough Spaw or a description of the nature and vertues of the spaw at Scarbrough, Yorkshire. Also a treatise of the nature and uses of sea, rain, dew, snow, hail, pond, lake, spring and river waters. Where more largely the controversie among learned writers about the original of springs is discussed. To which is added a short discourse concerning mineral waters etc.*, York and London, 1667.

[36] Ibid., p. 137–139.

fancied by Dr. Jorden, through the secret channels of the Earth, requires a man of much credulity to believe him . . .".[37] Instead, Wittie thought, rain and snow were much more likely to provide the source of spring waters. He cited as evidence in favour of this view the common observation that springs are fuller in winter than in summer; in dry climates very few springs are found, and in the very dry years between 1654 and 1656 most of the English springs had dried up.

Wittie described his five principles in terms of the four qualities. Vitriol, he held to be hot, biting, stiptic, and "astrictive". It would dry up superfluous humidity and was therefore useful in moist diseases; it stopped bleeding and would kill and expel worms. Iron, dry in the third degree, was also stiptic and would dry up superfluous humidity; it was said to be good for the liver, spleen, stomach, and against dropsies. Alum was held to be heating and corrosive, whilst nitre was drying, digestive, and "resolving", cutting gross and clammy humours. The last of the five, salt, was not thought to have any special medicinal virtue. Though Wittie claimed that the water was safe to drink, ". . . yet it cannot be expected by any rational man, that it should cure all diseases . . . ",[38] and yet, since it first cooled and moistened and was later hot and dry, it exhibited all four qualities. Since "most diseases consist in the excess of some one or more of them, each quality in exceeding is tempered by its contrary in the water . . .",[39] and so, despite his disclaimer, he appears to have considered the water a more or less universal remedy. He wondered whether it might not be possible to prepare an effective medicine by extracting the salts from the water by evaporation. Indeed, he claimed to have used small quantities of these salts to good effect, but thought that because it was necessary to use fire in extracting them, they gained added heating and drying qualities which made them too sharp for most purposes.[40]

Wittie's book was mainly of local interest and it drew an attack from a local rival, William Simpson, a young physician lately arrived in York. Simpson, whose father was a brewer, was an experimentalist who preferred the laboratory to the study. He was attracted by the Helmontian theory of ferments as the active agents in chemical change. In 1669 he published a critique of Wittie's book in an attempt to press the claims of "chymical Physick".[41] He first took issue with Wittie over the five principles, claiming that if vitriol and iron were both present they would form only one principle and not two.[42] If Wittie had meant that vitriols of *both* copper and iron were present, Simpson, with a clearer concept of chemical combination, said, ". . . Mars cannot be dissolv'd and appear in the form of a liquor, without a dissolvent; but this dissolvent viz., the Essurine acidity, being already satiated and turned into a vitriol, to make

[37] Ibid., p. 74.
[38] Ibid., p. 148.
[39] Ibid., p. 154.
[40] Thomas Guidott later extracted the salts from Bath water for sale. *A letter concerning some observations lately made at Bathe, written to his most honoured friend . . . by Thos Guidott*, Bath, 1674, pp. 5–7. This was at least five years before Nehemiah Grew exhibited crystals of the "bitter purging salt" to the Royal Society (see note 87 below).
[41] William Simpson, *Hydrologia chymica: or the chymical anatomy of Scarbrough and other spaws in Yorkshire. Wherein are interspersed animadversions upon Dr. Wittie's lately published treatise of the Scarbrough Spaw*, London, 1669.
[42] This point was also made in a letter from Nathaniel Highmore to John Beale published in *Phil. Trans. R. Soc. Lond.*, 1669, 4: 1128–1130.

up one of Dr. Wittie's precarious Principles, is not at leisure to make another of them . . .".[43]

On the question of how the minerals find their way into the water, Simpson was critical of three of Wittie's four suggestions, accepting only the second. He denied that a metal could give up any vapour to the water and rejected Wittie's third proposal as self-contradictory, for, "In every extraction is required a Menstruum or Solvent, and a body to be dissolv'd; but here according to his Theory, the Solvent and Soluable, are both one [i.e. vitriol]."[44] The fourth method, which was neither more nor less than transmutation, Simpson treated with ridicule. Far from being a philosophical idea, it was positively "rustical" to judge a mineral or metal to be transmutable into water merely because it seemed so to the vulgar eye. Thus Simpson, despite his emphasis on experimental observations, endeavoured to introduce an element of rationalism into the study of mineral waters.

To secure the widest local publicity for his criticisms of Wittie, Simpson took his arguments to the coffee houses of York where Wittie himself also began to appear in order to defend himself and refute his rival. Some time in 1668–69 Simpson challenged Wittie to join him in experiments on the Scarborough water at its source, no doubt hoping to obtain even more publicity. He arrived at the spring armed with five flasks each containing a solution of one of Wittie's five principles in pure water.

> So when we came to the Well, I desired an essay might be made of the mixture of these five solutions in fresh water, to try if we could imitate the *Spaw* thereby; he [Wittie] told the company that I expected from these Minerals which had undergone the fire, to see the same as from those which had not passed the fire; I answer'd, they were naked and bare solutions of the Mineral Ingredients, made without any stress of fire, and therefore might well be taken to make experiment withal; when he seemingly refus'd it, I called for a porrenger of fresh water, and put some of each of these solutions in, tasting it after each distinct Ingredient was put in.[45]

When tasting proved inconclusive, Simpson tried chemical tests. He first compared the action of galls on the mineral water and on his solution of alum, showing that in each case an inky precipitate was produced and that spirit of vitriol would clear both. He also found that oil of tartar (potassium carbonate) gave a white precipitate with both samples which spirit of vitriol would clear.

It had been found that the Scarborough water did not retain its curative properties when stored or transported from the spring, and Wittie held that this loss was due to the escape of "vitrioline spirits". Simpson was doubtful about this, and one of the bystanders who had gathered to watch the tests asked Wittie if he thought the same loss would occur if the water were kept in tightly sealed bottles. When Wittie replied that he thought it would, Simpson retorted that in that case it could not be due to the loss of volatile spirits. He wondered that Wittie had never thought of distilling the water in an effort to collect a sample of the spirits, though, "If you view the Doctor's tools by which he undertakes to hew out the rudiments of the Spaw, they are indeed very rude, and of a low rank, *viz,* a skellet, a culinary fire, but not a word of

[43] Simpson, op. cit., note 41 above, p. 3.
[44] Ibid., p. 12.
[45] Ibid., pp. 37–38.

a glass Still, which an ingenious Artist supposing volatile spirits would rather have chosen for the satisfaction of himself and the World."[46] This jibe undoubtedly stung Wittie, who, although he adhered to the methods of traditional medicine, nevertheless prided himself on his use of practical experiment. He had pointed out at the beginning of *Scarbrough Spaw* that Galen himself had condemned empirics and had encouraged the study of medicines and their effects by *trial* as well as reason. In fact, when challenged about his assertion that nitre was the principal mineral in the water, Wittie appealed to the results of some experiments he had made. He described how he had first added galls to the water, filtered off the precipitate, and then partially evaporated the remaining solution. A white curdling matter was separated. Then, after cooling, a further white precipitate was formed, which Wittie claimed to be the nitre from its taste. Finally, having decanted off the liquor, he had evaporated it to dryness in order to leave the remaining minerals. Now, although Simpson was critical of this procedure, pointing out that there was no reason to suppose that the first white precipitate was different from the second, the fact remains that Wittie, the traditionalist, *was* prepared to use experiments in his efforts to examine this mineral water.

Simpson stated that in his opinion the spa water contained "an acid alumenish mineral salt preying upon and dissolving a slight touch of the Minera of Iron . . .". He offered evidence for this by showing that when fresh water was mixed with a darkish yellow earth found in the cliffs near the spring and the mixture was filtered, the resulting solution resembled the spa water. The two samples showed the same reactions with galls, oil of tartar, spirit of hartshorn, and strong acids such as oil of vitriol and *aqua fortis*. Finally, he distilled the two samples and showed that the residues were identical. "All which put together, evince no less than a parity or likeness of Principles between that mineral earth and the Spaw water; for from a parity of Principles in a homogeneous process results a likeness of products . . .".[47] As to how these minerals had found their way into the water, Simpson said, God had in the beginning placed a variety of mineral and metalline seeds in hidden places in the Earth and from these, by the action of an "archaeus", the different mineral deposits or "glebes" were formed. The water flowing over these contained an acid, essurine salt which taught, ". . . Minerals and Metals how to dissolve in water by breaking them *in minima,* and thereby how to communicate their medicinal virtues for the health of man's body."[48] Moreover, the art of the chemist should be seen as complementary to that of Nature and should be used to refine and improve the medicinal properties of mineral waters. The physician must employ the same chemical techniques as are active in nature if he would put these waters to the most effective use. Disease, too, was due to faulty chemical processes arising from the incorrect action of the ferments in the various stages of digestion, and mineral waters acted by correcting these faults and restoring the digestive processes of the stomach, spleen, and other organs. Thus, both in their formation in the Earth and in their

[46] Ibid., p. 47. Daniel Foot, op. cit., note 25 above, also criticized Wittie for the view that mineral waters lose their virtue by loss of volatile spirits.

[47] Simpson, op. cit., note 41 above, p. 54.

[48] Ibid., p. 59. This was, of course, purely Helmontian.

curative action in the body, mineral waters were to be explained in terms of chemical fermentation.

Wittie replied to Simpson's criticisms in a book entitled *Pyrologia Mimica,* because he said, ". . . his [Simpson's] main business is to treat of Chymical Experiments prepared out of Fire, which he borrows from others . . .".[49] Wittie pointed out that although his ciritic began by denying his five principles except alum, yet before the end of his discussion he had accepted them all. This was in fact true.[50] Wittie now revealed that he too had a laboratory where he had made chemical medicines and used them in the past, though without much success. Still, "I would not be thought as if I were an Enemy to the Chymical Way, or those that are Learned Professors Thereof . . . I account it a singular Additament and Ornament to the Noble Art of Physick and the most useful Part of Experimental Philosophy."[51]

In the same vein and in order to establish some claim as an experimenter, Wittie replied to criticisms by Daniel Foot and Nathaniel Highmore with the remark that he had returned to Scarborough Spa "to renew my Experiments; wherein I resolv'd to be more critical." This reply, published in the *Philosopical Transactions*, was made in a letter to Henry Oldenburg and was accompanied by samples of the salts and residues obtained by Wittie from the spa water, together with descriptions of the methods used to obtain them. These included evaporation, crystallization, and filtration, and ended with distillation of the final residue on a sand bath until an acid spirit was evolved.[52] Wittie, a man of the world, seems to have been well aware of the advantages to be gained from compromise and the use of the best aspects of both systems of medical practice. By 1680, Wittie and Simpson had resolved their differences. Simpson, by then himself an established physician, published a book in which Wittie's successful cures using the spa water were sympathetically described.[53]

At the same time as he was engaged in the dispute with Simpson, Wittie was also involved in an argument about Scarborough Spa with George Tonstall, another chemical physician who was mainly concerned about claims made for the effectiveness of the water against the stone.[54] He had undergone an operation for the stone in 1666, and three years later had taken the waters at Scarborough only to suffer a fresh "fit of the stone". As evidence that this had been brought on by the water, Tonstall described distillation experiments in which quantities of sand, clay, and "stone

[49] Robert Wittie, *Pyrologia mimica or an answer to hydrologia chymica . . . in defence of Scarbrough-Spaw. Wherein the five mineral principles of the said spaw are defended against all his objections by plain reason and experiment . . . Also a vindication of the rational method and practice of physick called Galenical and a reconciliation betwixt that and the chymical etc.*, London, 1669.

[50] Simpson, in op. cit., note 41 above, named besides alum, iron (pp. 39, 44–45), vitriol (p. 359), and nitre (pp. 360, 364), as constituents of the water. The presence of common salt was assumed from the origins of the water in the sea.

[51] Wittie, op. cit., note 49 above, 'To the Reader' [no pagination]. A reviewer of this book in *Phil. Trans. R. Soc. Lond.*, 1669, **4**: 999, remarked that the difference between Wittie and Simpson, ". . . whether in the Matter, which concerns these Mineral Ingredients . . . or in that which respects the two ways of practising Physick, the Galenical and the Chymical, is indeed not so great as the heat of Contention seems to make it."

[52] Wittie, ibid., **5**: 1670, 1074–1082.

[53] William Simpson, *An historical account of the wonderful cures wrought by Scarbrough Spaw, etc.*, London, 1680. Simpson had never disputed Wittie's *use* of the water.

[54] George Tonstall, *Scarbrough Spaw spagyrically anatomized*, London, 1670.

powder" were deposited. Wittie rejected the criticism with the remark that the water had merely revealed a stone which must already have been present. Simpson also questioned Tonstall's conclusion.[55] Tonstall was not convinced, however, and on the basis of his experience continued to distrust the Scarborough Spa.[56]

IMITATING NATURE

With his understanding of the generation of minerals and metals in the Earth and how they were dissolved in water, the chemical physician sometimes thought that he could imitate and even improve upon Nature:

> . . . The Chymistry of nature is most admirable, which by its own peculiar Menstruums extracts the essential innate virtues of Mineral Glebes, and that by an intrinsick invisible fire in the digesting vessels of the Earth, yea and by the help of Art, supplying the difficulties of Nature, by frequent solutions and coagulations may yet further graduate these mineral virtues into more noble Arcana's whose essential tinctures may the better penetrate the vital ferments of the Microcosm.[57]

It seemed possible to strengthen the curative powers of weak mineral waters, either by adding more of the salts they already contained or by taking them in conjunction with other medicines.[58] Furthermore, a natural mineral water might be copied by chemical means, and it was even possible that the artificial product might be more effective than the natural one, if only because the grosser earthy impurities could be avoided. Timothy Byfield, an Irish physician living in London, applied chemical methods to the analysis of mineral waters, and having carefully ascertained what "Minerals, Marcasites and Nitrous glebes" they contained, prepared artificial mixtures and also more concentrated tinctures of the salts for sale.[59] John French also suggested methods of preparing artificial Tunbridge and Epsom waters.[60] The chemical physician was often prepared to ignore any undefined virtue which a natural mineral water might be thought to derive from its origins in the Earth, and to place all his faith in the simple chemical effects of the purified salts and minerals it contained.

> If then the Natural Medicinal Waters receive their Virtues from Minerals and Marcasites unprepar'd, only by washing on 'em as they pass through the Caverns and Veins of the Earth, and are esteemed of so great use: of how much more certainty then in their operation and

[55] Simpson had replied to Wittie's *Pyrologia mimica*, (op. cit., note 49 above) in his *Hydrological essays, etc., To which is annexed an answer to Dr. Tonstall's book concerning Scarbrough Spaw*, London, 1670. Wittie criticized both writers in *Scarbrough's spagyrical anatomiser dissected. Or an answer to all that Dr. Tonstall hath objected in his book against Scarbrough Spaw . . . As also reflections upon a late piece . . . called a vindication of Hydrologia chymica*, London, 1672.

[56] George Tonstall, *A new-years gift for Doctor Witty; or the dissector anatomized, etc.*, London, 1672.

[57] Simpson, op. cit., note 41 above, p. 59.

[58] P. Bellon, *The Irish Spaw; being a short discourse on mineral waters in general with a way of improving by art weakly impregnated mineral waters and a brief account of the mineral water at Chappel Izod near Dublin etc.*, Dublin, 1684.

[59] Timothy Byfield, *The artificial spaw, or mineral waters to drink: imitating the German spaw water in its delightful and medicinal operations on humane bodies*, London, 1684. Byfield's artificial mineral waters were on sale in London at sixpence per bottle, or five shillings for a bottle of concentrated tincture which could be diluted to make ten or eleven quarts of mineral water.

[60] John French, *The art of distillation; or a treatise of the choicest spagyricall preparations performed by way of distillation . . . etc.*, London, 1651, pp. 165–167.

> usefulness must the Artificial Waters be, which have their Minerals purg'd and cleans'd from all their foul and noxious parts . . . .[61]

Nevertheless, there was some opposition to the use of such artificial preparations, even amongst those who otherwise accepted mineral substances as useful items of materia medica. For example Edmund Borlase, a physician who was well aware of the value of chemical medicines, expressed doubts about the artificial mineral water, "I cannot approve of such fictitious waters . . . I am not convinct that Art (though in some great Masters of it, it may arise to a wonderful Excellency) can yet ever so deliciously compose medicines to equal the refin'd Spirits, which God and Nature with so much Curiosity mixt in the Bowels of the Earth . . .".[62] But, whether or not artificial mineral waters were effective, it could not be doubted that the only way to learn the exact composition of the natural products was by chemical analysis. In this the chemical physicians played an important role; they were engaged in preparing chemical medicines to be administered to their patients and, as Byfield pointed out, had to know ". . . the Poyson from the Medicinal quality . . .",[63] as well as the best methods of extracting, preparing, and purifying the salts and minerals used.

CHEMICAL ANALYSIS OF MINERAL WATERS

Most of the available tests were qualitative, lacking precision, even though the need for improved accuracy had been recognized.[64] The importance of careful observations was regarded as paramount, although these were mainly concerned with the colour, taste, and smell of the water, together with its effects on galls and a few other vegetable extracts. Acidity was often recognized by testing the water for its power of curdling milk as well as its reactions with oil of tartar and other alkaline substances.[65] Mineral waters were frequently found to deposit an earthy sediment, or ochre, on standing —a fact which was taken as a clear indication that some continuing chemical process was involved. The formation of both the mineral components of the water and any sediment it might produce was sometimes expressed in terms of the current acid-alkali and corpuscular hypotheses. Thus, Samuel Derham, describing these effects in the Ilmington Water, wrote,

> . . . when they [an acid and an alkalizate body] are in proportionate quantity the conflict betwixt these contrary Salts is great, but the Acid . . . fixeth its points in the pores of the Alkalizate Matter; yet hath not power to shatter it all to pieces, and free itself from combinations: but the Parts of the Acid lie sheathed and loaded with Alkali. So that they being closed together, do by their own weight . . . fall down to the bottom . . . and combined together, do become a Neutral Salt.[66]

The residue was found to effervesce with acids, but showed no reaction with spirit of

[61] Byfield, op. cit., note 59 above, p. 35.
[62] Edmund Borlase, *Latham Spaw in Lancashire*, London, 1670, 'Epistle Dedicatory' [no pagination].
[63] Byfield, op. cit., note 59 above, p. 31.
[64] A. G. Debus, 'Solution analyses prior to Robert Boyle', *Chymia*, 1962, **8**: 41–61; Ferenc Szabadváry, *History of analytical chemistry*, Oxford, Pergamon Press, 1966, pp. 29–40.
[65] Derham, op. cit., note 23 above.
[66] Ibid., p. 78.

hartshorn (strong solution of ammonia). Derham also concluded that nitre could not be acid salt, as was commonly thought.[67] He attempted to achieve greater accuracy in the test for iron by dividing separate one-grain quantities of the powder of galls into twenty, nineteen, eighteen, etc., parts, and taking one part from each division dissolved in separate pints of the spring water. In this way he found that the first coloration from iron became visible with one-eighteenth of a grain of powdered galls in one pint of the water, and he concluded that the Ilmington water was therefore one of the strongest of the simple English chalybeates. He confirmed his opinion by comparing the mineral water with known solutions of iron vitriol (ferrous sulphate) in fair spring water, and he also noted its medicinal effects in comparison with those of Epsom, Scarborough, and Barnet, to emphasize its differences and to confirm that it did not contain either alum or nitre.[68]

Further differentiation of chalybeate waters was proposed at the end of the century by Benjamin Allen, an Essex physician,[69] who claimed to distinguish between chalybeates having a "spirituous" component and those containing a salt similar to nitre. The chief difference seems to have been in their specific gravities—the former being lighter than the latter. The heavier waters were less effective medicinally "and the more nitrous the worse".[70] Allen's chemical tests included, besides the usual galls and vegetable colours, silver nitrate and corrosive sublimate as a measure of alkalinity, but he said, "I have not found any of this kind [i.e. heavy chalybeates] so fully nitrous or Alkalizate, as to trouble a solution of Sublimate, much less precipitate it Yellow . . .".[71] Allen could have benefited from recent improvements in analytical technique made especially by Boyle, but he seems to have been unaware of them. His book contains no reference to Jorden, Boyle, or Grew, though he mentioned the work of Derham, French, and Willis.

Significant improvements in mineral water analysis were suggested by Robert Boyle in 1684 (see Fig. 3).[72] The chemical and physical techniques in his *Short memoirs* far surpass anything done previously, and represent an advance in inorganic analysis, both qualitative and quantitative. Having carefully noted the exact position of the spring, the nature of the surrounding rocks, and the appearance of the water

[67] Simpson, op. cit., note 55 above, p. 142.

[68] The effects of the waters in use were always regarded as an essential part of any examination and more reliable than knowledge of chemical contents. Wittie recommended Scarborough water because "Nothing is plainer every day than this, to finde Stones expelled at these Waters . . .", *Scarbrough's spagyrical*, op. cit., note 55 above, p. 40; William Petty in proposing a programme of thirty-two tests for examining mineral waters included thirteen medicinal tests, but only about eight physical and chemical ones, *Phil. Trans. R. Soc. Lond.*, 1684, **14**: 802–803; In the same year Boyle wrote "the surest way of knowing them [i.e. mineral waters], is a long and sufficient Experience of their Good and bad effects . . .", *Short memoirs for the natural experimental history of mineral waters*, London, 1684/5 [*sic*], p. 3.

[69] Benjamin Allen, *The natural history of the chalybeate anad purging waters of England etc.*, London, 1699. For biographical material on Allen see, R. M. Christy, *Dr. Benjamin Allen, 1663–1738, of Braintree; a forgotten Essex naturalist*, 1911; *More about . . . Allen*, 1912, (both reprinted from the *Essex Naturalist*).

[70] Allen, op. cit., note 69 above, p. 17.

[71] Ibid., p. 18. Allen described the crystalline form of the purging salt with a diagram (p. 184) taken from Martin Lister, *De fontibus medicatis Anglicae*, York, 1682; London, 1684.

[72] Boyle, op. cit., note 68 above. The *Short memoirs* consisted of a collection of notes for a more comprehensive work which was never completed.

as it issued from the ground, Boyle agreed that it would be *possible* to estimate approximately the coolness or heat of the water by noting whether it would coagulate

FIGURE 3
Boyle's Scheme for the Examination of Mineral Waters
(Summarized from *Short memoirs for the natural experimental history of mineral waters*, London, 1684/5 [*sic.*])

	Test	Effects, Observations and Queries
1.	Thermoscope	Heat or coldness of the mineral water.
2.	Hydrometer	Specific gravity.
3.	Appearance	Transparency, opacity, colour.
4.	Microscope	What kinds of infusoria in the water?
5.	Effect of standing exposed to air or in scaled vessels.	Deposit of ochre or earthy matter—distinction of residue from *caput mortuum*.
6.	Heating and cooling; freezing to ice and thawing.	Comparison of rate of heating and cooling with ordinary water.
7.	Odour	Acetous, winy, sulphureous, bituminous.
8.	Taste	Acid, ferruginous, vitriolate, lixiviate, sulphureous.
9.	Viscosity, or "thinness".	
10.	Putrefaction	Whether sooner or later than ordinary water; smell.
11.	Galls, oaken leaves, red roses, logwood, Brazil, pomegranate peel, *lig nephriticum*, etc.	Colour changes indicating acidity, alkalinity, presence of iron, etc.
12.	Precipitation with salts or saline liquors	(a) acid; spirit of nitre; aqua fortis. (b) alkali; spirit of urine; sal ammoniac. (c) lixiviate; oil of tartar *per deliquium;* fixed nitre.
13.	Tests for common salt	Does it lather or curd with wash balls or soap? Does it boil peas tender?
14.	Residue after distillation—*caput mortuum*	(a) Proportion of dry *cap. mort.* by weight. (b) Proportions of saline and terrestrial parts. (c) Does residue yield original mineral water again when added to fair spring water?
15.	Saline part of *cap. mort.*	(a) Is it fixed or volatile in strong heat? (b) Crystalline? If so, what is the crystalline shape; if not, does it combine with a salt to form crystals? (c) Is it predominantly acid, alkaline, or 'adiaphorus?' (d) If acid: taste, odour, effect on corals or finely powdered crabs eyes, precipitate with oil of vitriol, spirit of salt, oil of tartar, spirit of urine. (e) If alkaline: lixiviate, taste, smell, action on vegetable colours, precipitate wtih sublimate mercuric chloride, effervescence with *aqua fortis* or well dephlegm'd spirit of salt.
16.	Terrestrial part of *cap. mort.*	Colour, odour, volatile or fixed? Solubility in spirit of vinegar or of urine, etc. Proportion of loss on strong heating, colour change, vitrification and fusion with powdered Venice glass.
17.	Uses—as these may arise in discovering the ingredients and qualities of mineral water.	Brewing; baking; washing linen; tanning leather; dyeing cloth, calico, silk, etc.
18.	Imitation of the natural mineral water by chymical and other artificial ways.	

essential oils of anis or fennel seeds, or, alternatively, melt butter, tallow, beeswax, etc., or even coagulate the whites of eggs, but, ". . . the best way is to plunge in the water . . . the whole Ball or globulous part of a good hermetically seal'd Thermoscope, whereon the degree of cold and heat are carefully mark'd."[73]

He agreed too, that it was important and useful to know the specific gravities of mineral waters, but it was necessary to have good instruments. Physicians commonly weighed the water in some apothecary's or other tradesman's shop, where often the vessels full of water were too heavy for the small balances and must therefore have produced inaccurate results. In fact, Boyle said, it was so difficult to weigh liquors exactly that he felt unable to rely upon any of the results obtained by the common methods.[74] More skill and better instruments were needed, and he therefore described a hydrometer which he had devised for comparing the specific gravities of mineral waters—a much simpler and more accurate device.

> . . . I chose to make a very skilfull Artist blow; at the flame of a great lamp, a thin round vial with a flatish bottom, that it might stand upright, and be very light, and this was furnish'd with a neck as large as a Goose quil drawn very even into a hollow Cylinder of above three inches long, and fitted at the top with a little Cap, that hinder'd the water from ascending above the due height. . . .[75]

Regarding tests with the vegetable colours, Boyle insisted that fresh material should always be used and that the dry powders were preferable to infusions. When the latter were employed, he made them of standard strengths.

> I make my infusion of Galls with a certain weight of the Powder in a determinate weight of water. As for instance I put about five grains of powder'd Galls, to steep for so many hours in an Ounce of Water. But if I make use of the dry Powder, then I am wont to put three or four grains into an Ounce of the liquor to be examin'd; which is a way far more certain than the Common, wherein the Ingredients are estimated but by Guess.[76]

An even more important innovation introduced by Boyle was to soak sheets of white paper in strong solutions of vegetable colours and allow them to dry in the air. These test papers were then used in a "spot-test" technique in which single drops of various mineral waters were placed on them side by side so as to compare the effects. This method would rank Boyle as a pioneer in qualitative analysis, although there is no evidence that it was widely used, either by his contemporaries or by eighteenth-century chemists.[77]

[73] Ibid., p. 64. Boyle had first used sealed alcohol thermometers about 1665 in his *New experiments and observations touching cold . . .*, Thos. Birch, *The works of the Hon. Robert Boyle,* 5 vols., London, 1744, vol. 2, pp. 249, 264; vol. 3, p. 570. Hooke was also experimenting with sealed alcohol thermometers about this time. R. Hooke, *Micrographia,* London, 1665; reprinted, New York, Dover Publications, 1961, p. 38.

[74] Boyle, op. cit., note 77 below, p. 67.

[75] Ibid., p. 68. Boyle had first demonstrated his hydrometer at a meeting of the Royal Society on 7 May 1662. *Journal Book R. Soc. Lond.*, vol. 1 (1600–64), p. 58. He later extended its use to the assay of coins and precious metals, *Phil. Trans. R. Soc. Lond.*, 1675, **10**: 329–348.

[76] Boyle, op. cit., note 68 above, p. 36.

[77] R. G. Neville, *Isis,* 1958, **44**: 438–439. For a contemporary review of Boyle's *Short memoirs,* see *Phil. Trans. R. Soc. Lond.*, 1685, **15**: 1063.

Having examined the mineral water itself, Boyle next evaporated it to dryness to test the residue. He added it to water again, noting what proportion redissolved and filtering to separate the earthy and saline parts. Each was then examined separately by the ordinary tests, which Boyle was quick to show were inconclusive. But, after all the chemical tests had been exhausted, in good Baconian tradition he proposed to examine the effects of the mineral water in use, both as a medicine and in various manufacturing processes.[78]

In the course of his tests Boyle had recognized the presence of elementary sulphur in certain mineral waters and of bituminous or oily matter mixed with others. He had distinguished between these two constituents whilst recognizing that they might sometimes occur together. Jorden had also, long before, distinguished between sulphur and bituminous matter in mineral waters,[79] and even in 1631 had refuted the traditional notion that bitumen would burn under water. "For although water were a fewel to fire, as oyl is, yet there can be no fire without air, and water excludes air . . .".[80] Regarding Bath water, Jorden held that it might contain a slight touch of sulphur mixed with its bituminous constituent, but there could not be very much sulphur present since the Bath water was clear and not milky. Nevertheless, its heat supported the idea that it must be in contact with hot sulphurous vapours in the Earth, though he knew that not all sulphurous waters were hot. Derham, knowing that sulphur, like oil and bitumen, was insoluble in water, said that it would either fall with any sediment formed or remain in the residue after evaporation. In either case it could be recognized by the fact that it would burn with a blue flame and a characteristic smell.[81]

Byfield suggested that bitumen was merely a different *form* of suphur, fabricated within the Earth. Describing a newly discovered "balsamic" Well at Hoxdon in London,[82] he said that the balsamic principle, though well digested and purified by the volatile salt, still contained a good proportion of the "embryonate sulphur" of the Earth and, although this had been made very volatile, it was held down in the water by the presence of vitriol of iron. On evaporating the water, the iron was precipitated and the balsamic principle was released as a vapour. Yet this was not a sulphurous spa, for it had no smell of rotten eggs. Thus, the water contained sulphur in principle but not in fact; there was clearly a problem of conceptualization, and the Helmontian had as much difficulty as the Galenist in expressing his meaning without ambiguity.

NEHEMIAH GREW AND THE EPSOM SALT

Boyle was not the only member of the Royal Society to show an interest in the chemical and medicinal properties of mineral waters. Others included John Beale,[83]

[78] See note 68 above.
[79] Jorden, op. cit., note 6 above, p. 34.
[80] Ibid., p. 35.
[81] Derham, op. cit., note 23 above, p. 60. Derham based his remarks on Simpson, op. cit., note 55 above, p. 61.
[82] T. Byfield, *A short and plain account of the late-found balsamick wells at Hoxdon and of their excellent virtues above other mineral waters; which make 'em effectually cure most diseases both inward and outward etc.*, London, 1687.
[83] J. Beale, *Phil. Trans. R. Soc. Lond.*, 1665-66, **1**: 358–360.

William Petty,[84] and especially Nehemiah Grew, who not only made a detailed study of the salts in the Epsom water, but also developed a business interest in extracting these and other salts from mineral waters, for sale. Grew had exhibited the Epsom salt at the Royal Society on 5 June 1679, when he read a paper on the mineral springs around London.[85] In the Epsom waters he found a mixture of common salt and another which he called the "bitter purging salt", the properties of which he very thoroughly examined. He used the microscope to identify the shape of its crystals, and applied other physical tests including solubility and the specific gravity of solutions of fixed strength. Amongst chemical tests, Grew tried the effects of heat and of strong sulphuric acid, both of which produced little change. He also noted that the salt after calcination remained virtually unaffected by exposure to the air, unlike the residue from the calcination of limestone, for example. It gave no colour with galls and was therefore devoid of iron, and in tests in which it was compared with alum, Grew was able to distinguish betwen the two substances, as he was also to differentiate between the Epsom salt and common salt, nitre, and calcareous salts. He compared the solubilities of these salts, noting for example that calcareous salt (calcium carbonate) required 640 times its own weight of water to dissolve, whilst the bitter purging salt would dissolve readily in not more than six times its own weight. In comparing this salt with nitre, Grew tried to obtain aqua regia from both by distilling them separately with "Dantzick vitriol". Failure to obtain the desired result with the bitter purging salt distinguished it from nitre, and from this result, together with those of his other tests, Grew showed that this salt was quite distinct from any other known to occur in mineral waters. In 1695 he published his results in a Latin treatise describing both his methods of extraction and the tests he had performed, together with some account of the medicinal properties of the salt.[86]

Grew had set up a salt works at Acton Wells in London, where this and other salts were extracted from various mineral springs near London in large quantities, and a number of London apothecaries and chemists began to buy his products for sale in their shops. Grew's methods of making these salts pure, cheaply, and in sufficient quantities for trade purposes were considered to be an important invention, for which he was granted a Royal Patent. Christopher Wren, in 1698, testified that Grew had been the first to exhibit such salts to the Royal Society, "I do remember, that about nineteen years past, Dr. Grew showed to the Royal Society at one of their Meetings in Gresham College, several Parcels of Crystallised Salts, by him made of the Purging Waters about London. And I do not remember, that any salts of that Sort, were before that time, presented to the Society by any Person . . .".[87] Trade in these salts was brisk; revenues were considerable, and it was projected that a

[84] See note 68 above.

[85] *Journal Book R. Soc. Lond.*, vol. 5 (1677–82), 5 June 1679. The substance of Grew's paper was not recorded.

[86] Nehemiah Grew, *Tractate de salis carthartici amari in aquis Ebeshamensibus et hujismodi aliis contenti natura et usu*, London, 1695.

[87] Testimony by Christopher Wren, 4 June 1698, quoted in Josiah Peter, *Truth in opposition to ignorant and malicious falshood* [*sic*], *or a discourse written to vindicate the honour and to assert the right of Dr. Nehemiah Grew . . . with respect to his invention for making the salt of the purging waters etc.*, London, 1701, pp. 27–28.

production of 20,000 lbs. per annum, for this country alone, might be possible.[88] This gave rise to many attempts to counterfeit the salts, despite Grew's patent. None of the pirated products was as pure as the original, and some were even said to be dangerous, which tended to give the genuine product a bad name.

Amongst the offenders none was more persistent than the brothers George and Francis Moult, who first began to buy Grew's products from his operator at Acton. Then Francis commissioned an English translation of Grew's *Tractate* and supplied a copy free to each customer.[89] By this time the Moults were extracting their own salts from a spring at Shooter's Hill,[90] and it became evident that action was needed to put a stop to their activities. Grew therefore issued a more accurate translation of his *Tractate*, with criticisms of the pirated version.[91] At the same time he placed the defence of his patent rights in the hands of Josiah Peter, who undertook to collect and set down the evidence in support of Grew's prior claim as the inventor of the method of extracting pure crystals of the bitter purging salt from mineral waters. Peter's evidence also made clear the special merits of Grew's own products, particularly their purity.[92] but the Moults' illegal activities were curtailed only with great difficulty. Francis inserted an advertisement into four London newspapers claiming that he was, ". . . the only Person of his Trade or Profession in London, who hath, for some Years last past, prepared and sold the Bitter Purging Salt, from Mineral Waters; and continues to do so, notwithstanding any Power or Authority of Dr. Nehemiah Grew to the contrary."[93] Grew attempted to come to a legal agreement with the Moults, but only succeeded in imparting to them more and more of the details of his techniques, until they began to claim that they now made the salt "under Dr. Grew's direction".

[88] One interesting development was the carriage of these salts to other spas. Grew's Epsom salt had already been exhibited at Tunbridge Wells by Daniel Whistler (Munk, op. cit., note 3 above, vol. 1, pp. 249–251) in 1679, though it was taken as a medicine with the Tunbridge chalybeate only after 1695. The salts also solved some problems of the carriage of mineral waters themselves from one spring to another. Thus, Sir John Floyer wrote to Grew, 24 October 1700, ". . . We formerly sent for the waters of Barnet or Northhaw [*sic*] to Lichfield, which could seldom be procured under 14 Days; and they were frequently come putrid, or were so, before we used much of them. But since we have had plenty of Your Salt, we have not sent for any of the mentioned Waters . . .", quoted by Peter, op. cit., note 87 above, p. 36. English trade in mineral waters developed during the eighteenth century, see Sylvia McIntyre, *J. Trans. Hist.*, 1973, N.S., **2**: 1–19.

[89] N. Grew, *A treatise of the nature and use of the bitter purging salt contained in Epsom and other such waters*, trans. by Francis Moult, London, 1697. This was such a bad translation that it was condemned in a statement signed by fourteen eminent physicians to the effect that the ". . . Translation, coming into the hands of those, who are Learned in Physick or Chymistry, and being by them believed to be truly Translated, as by the Translator it is averred to be: is highly scandalous, not only to the Author, but to the College of Physicians, and the Royal Society . . .", Peter, op. cit., note 87 above, p. 55.

[90] H. E. Roscoe and C. Schorlemmer, *Treastise on chemistry*, 5th ed., 2 vols., London, Macmillan, 1920–23, vol. 2, p. 643. The Moult brothers were able to produce between 150 lbs. and 200 lbs. of these salts per week.

[91] N. Grew, *A treatise of the nature and use of the bitter purging salt, easily known from all counterfeits by its bitter taste. Written originally in Latin . . . And now published in English by Joseph Bridges. With animadversions on a late corrupt translation published by Francis Moult*, London, 1697.

[92] Peter, op. cit., note 87 above, gathered evidence from members of the Royal Society, Royal Collges of Physicians of London, Edinburgh, and Dublin, Royal Academy of Paris, Imperial Academy in Breslau, and from eminent individuals at home and abroad.

[93] Ibid., p. 58. For this advertisement the Moults and the four newspaper publishers were reprimanded by the Lord Chancellor.

CONCLUSION

The increased number of mineral springs which came into use during the seventeenth century shows that this was a topic of great popular appeal. Most of these waters were equally available to all, whether rich or poor; they were free and the medicinal results obtained by their use were at least as favourable as any obtained by other contemporary methods of treatment. However, their apparent effectiveness in curing the diseases of the affluent (e.g. gout and stone), led to the re-instatement of old spas such as Bath, and the establishment of new ones like Tunbridge Wells and Epsom as fashionable resorts. Within easy reach of London, members of the Court commonly frequented these newer spas during the season for drinking the waters (May to July). After the Restoration Epsom wells became particularly fashionable;[94] Pepys records that the town was so full of visitors in 1663 that he was obliged to seek lodgings at Ashtead.[95] An easy drive from the Royal residences in London, at Nonesuch, near Ewell, and Hampton Court, encouraged Charles II, the Duke of York (later James II), and Prince George of Denmark to visit Epsom. Daily postal services, perhaps the first of their kind, were operated during the season between London and the new spas at Tunbridge Wells and Epsom from 1684.[96] Thus there grew up the fashion of visiting the spas to "take the waters" which was to reach its peak in the eighteenth century. The amenities provided at the spas were naturally in keeping with the social status of the clients.[97]

The many books and pamphlets explaining the nature of the different springs which were published in the seventeenth century were also written in a style clearly intended for the educated, with their inclusion of chemical and medical terms and their many classical allusions. It was commonly assumed that patients would be prepared and able to go to almost any of the known springs; the specific medicinal properties of the waters were carefully identified, and it is clear that seventeenth-century physicians who advocated this type of treatment placed strong emphasis on the curative effects of the chemicals they contained. In all cases, however, patients were urged to adopt a strict diet and regimen at least for the duration of the course of treatment.

The application of chemical theories and techniques to the study of mineral waters provided a vehicle for the medical ideas favoured by the chemical physicians. Allegorical, alchemical and semi-mystical descriptions of the formation and properties of mineral waters declined during the century, since Helmontian theories, involving the use of *archei* and ferments, provided a means of accounting both for the formation

[94] The well at Epsom had been discovered in 1618, *Vict. County Hist.*, (Surrey, vol. 3, p. 272), though Tobern Bergman claimed that the *sal. catharticus amarum* had been held in high esteem there since 1610, *Opuscula*, 6 vols., Leipzig, 1786–92, vol. 1, p. 75. Aubrey took the waters in 1654 and Henry More three years later, Marjorie H. Nicolson, *The Conway letters; the correspondence of Anne, Viscountess Conway, Henry More, and their friends, 1642–1684*, London, Oxford University Press, 1930, p. 144.

[95] R. C. Latham and W. Matthews (editors), *The diary of Samuel Pepys*, 9 vols., London, G. Bell, 1970–76, vol. 4 (1663), pp. 245–249. Pepys also records other visits to Epsom, e.g., vol. 8 (1667), pp. 336–338.

[96] *Gazette*, 19 June 1684.

[97] Epsom reached the height of its popularity between 1690 and 1715. J. Toland, *A new description of Epsom*, (1711), in *Miscellaneous works*, 2 vols., London, 1747, vol. 2, p. 61.

of mineral waters in the earth and for their action in the body. The chemical approach encouraged a more rational explanation of their effects; attempts to analyse the waters by chemical and physical methods posed problems, the solution of which fostered early analytical techniques and emphasized the need for standardization and improved accuracy. The use of chemistry in medicine was also evident in attempts by chemical physicians to prepare artificial mineral waters with the same composition and medicinal properties as the natural products, and it is interesting to note their claim that these artificial mineral waters might even be more effective than the natural ones on account of the stricter control of composition and especially of purity which was possible. Medical treatments thus became more frankly chemical due to these ideas and by the use of the crystallized salts themselves, either alone or in conjunction with other mineral waters. All these developments in seventeenth-century medicine may be considered as small and tentative steps towards the wider acceptance of physico-chemical methods in medical diagnosis and treatment.

SUMMARY

Mineral waters became popular in English medicine from 1570 onwards; old spas such as Bath and Buxton were revived, whilst new ones like Epsom and Tunbridge Wells became fashionable during the seventeenth century. Curiosity developed about the origins of mineral waters, their chemical composition and medicinal properties. Most physicians were influenced by these developments, but it was for the chemical physicians that the study of mineral waters exerted its strongest attractions. Edward Jorden, physician at Bath and an early writer on the subject, linked the chemistry of these waters to the wider study of chemistry and geology. Other chemical physicians took up the theme, showing both the similarities between terrestrial and laboratory processes and the possibility of copying natural mineral waters. The uses of chemistry in medicine were thus explored, whilst trade expanded both in mineral waters and in the salts extracted from them; Nehemiah Grew's "bitter purging salt" was perhaps the most notable example.

Some aspects of qualitative inorganic analysis were developed and standardized as a result of the study of mineral waters, culminating in 1684 in Boyle's *Short memoirs for the natural experimental history of mineral waters*, in which the first recorded use of "spot" tests is to be found, but quantitative analysis developed slowly. Volumetric analysis was unknown, though simple gravimetric techniques were used, as were instruments such as the hydrometer, thermometer, microscope, and balance. The correlation of analytical data on mineral waters with their medicinal uses was a small, though valuable, step in the application of physico-chemical techniques to medical practice.

In this paper some of the more important contemporary attitudes to these problems are discussed with copious references to source materials on mineral waters, mostly by minor and little-known seventeenth-century medical writers.

ACKNOWLEDGEMENTS

The author wishes to acknowledge gratefully the help received from the Librarians of the Royal Society, the Royal Institution, and Tunbridge Wells Public Library.