The historical roles of mineral materials in folk medicine and the development of the materia medica.

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This thesis is dedicated to the memory of my wife, Yvonne Duffin (1950-2015), who appreciated and supported my consuming interest in the subject investigated in these pages.

Abstract

Mineral materials include rocks, minerals, fossils, earths, mineraloids, biogenic skeletal remains and synthetic stones. Each of these classes of material has enjoyed much popularity as supposedly therapeutic medicinal ingredients in the history of pharmacy; many have an unbroken record of use since ancient and classical times. The historical *materia medica* incorporates minerals that have been made use of in both medical folklore and academic analysis. This thesis presents a body of work which develops examples from each class of mineral material, tries to establish their identities, and explores the evolution of their therapeutic use against the backdrop of changing philosophies in the history of medicine. The most rudimentary use of mineral materials was in a magico-medicinal way as amulets worn for protection against harmful influences which might be expressed in the body as loss of health, and as prophylactics against specific diseases and poisons. Amulets were often worn as pendants, necklaces and rings, or appended to the clothing in some way. The humoral system of Greek medicine saw the health of the body as being a state of balance between the four humours. Humoral imbalance was corrected by, amongst other interventions, the application of medicinal simples or 'Galenicals', which were largely unmodified (other than by trituration) herbal, zoological and mineralogical materials. The choice of simple was determined by the Aristotelian qualities ascribed to them, and their perceived efficacy according to the Doctrine of Signatures. This approach to prescribing practice held sway from classical times until the work of Paracelsus at the beginning of the Scientific Revolution which commended the use of only the active ingredients of a particular simple, separated from the remainder by alchemical means. These iatrochemical preparations permitted dosage standardisation and encouraged a more empirical approach to prescribing practice. The mineral materials most closely examined in this thesis in the context of the evolving *materia medica* are pumice, gemstones, holed flints, amber, unicorn horn, Jews' stones (fossil echinoid spines), Porcupine bezoars, otoliths and synthetic stones. The analyses presented here rely on the study of manuscript, archival, printed and material sources.

Contents

1. Mineral materials and medical folklore

1.1 Introduction

The elements of this study span from antiquity to the present day and have utilised a wide range of ancient and classical (including ancient Assyrian, Babylonian, Egyptian, Chinese, Indian, Greek, Roman and Arabic) written sources, medieval (encyclopaedias, leechbooks, bestiaries and lapidaries), early modern and modern texts, in order to trace the evolution of individual mineral materials as therapeutic agents. Duffin (2013e) provides background and contextualising information on some of the many texts consulted during this work (see also Duffin 2005). Manuscript and archive sources are detailed in individual publications as relevant.

Extensive use has also been made of elements of material culture held in a range of international, national and provincial museums and other historical collections, including those of the Metropolitan Museum of Art (New York), the Musée national d'histoire naturelle Luxembourg, the Staatliches Museum für Naturkunde in Stuttgart, the Boerhaave Museum in Leiden, the Staatliche Kunstsammlung in Dresden, the Schatzkammer und Museum in Vienna, the Kunsthistorisches museum in Vienna, the Forschungsinstitut Senckenberg in Frankfurt/Main, the Museu da Farmácia in Lisbon, the Pharmazeutisches Museum of the University of Basel, the Metropolitan Chapterhouse (Museo de Tapices de la Seo) of Zaragoza Cathedral, the Muséum d'histoire naturelle de Grenoble, the British Museum, The Natural History Museum, the Victoria and Albert Museum, the Booth Museum (Brighton), the Pitt Rivers Museum (Oxford), the Ashmolean Museum (Oxford), the Wellcome Collection, the Royal Pharmaceutical Museum, the Sedgwick Museum (Cambridge), and various colleges of Cambridge University. Specimens from these collections are discussed and illustrated in the various papers appended to this thesis.

Many of the simples (medicinal material – usually herbal in other works – used in treatments) under consideration are first recorded in the folklore traditions of ancient cultures (e.g. Roman folklore as recorded by Pliny the Elder, first century AD), but then became incorporated into mainstream medicine by authorities such as Galen (second century AD). Some items were predominantly amuletic (e.g. holed flints)

and often prophylactic in their action (e.g. fossil shark's teeth, fossil coral, fossil fish teeth, fish otoliths, Alectorius, stone powder from European churches). The popularity of these materials often relied on their supposed actions as alexipharmics (protectors against poisons). Vestiges of these beliefs have persisted to the present day, although some have been relegated to the category of 'lucky stones'. Others, whilst retaining amuletic standing, were incorporated as medicinal simples into a wide range of polypharmaceutical preparations administered in a huge number of different ways, utilising a wide diversity of delivery media (e.g. amber, 'unicorn horn', bezoar stones, lapis lazuli, the gem electuary).

The scholarly publications that are presented in this thesis were published between 2006 and 2017. They encompass work on mineral materials as incorporated into the *materia medica* (collected body of knowledge concerning medicines) from both folklore and academic sources, mostly from Europe but with extra-European contextualising material sometimes incorporated. Although primarily concerned with human medicine, the published works occasionally shed light on veterinary medicine as well. For the purposes of the present thesis this introduction has been arranged along thematic lines utilising the following classification of mineral materials :

(A) Inorganic minerals of abiogenic origin :
   a. Rocks such as limestones, sandstones, slate, lapis lazuli and pumice
   b. Minerals such as haematite, quartz, sapphire, ruby, turquoise, nephrite jade, chalcedony, agate, selenite, siderite, pyrite, garnet and cinnabar
   c. Earths such as terra sigillata

(B) Mineraloids – non-crystalline mineral-like substances :
   a. Inorganic mineraloids such as flint
   b. Organic mineraloids such as amber and jet

(C) Minerals of biogenic origin – the skeletal remains of
   a. Extant organisms such as whales (Narwhal) and gastropods (opercula)
   b. Fossil organisms such as echinoderms, fish, sponges, brachiopods, belemnites, foraminiferans and plants
   c. Endogenous concretions, non-skeletal in function but formed within the body, such as bezoars, otoliths and bladder stones.

(D) Artificial 'stones' which have been produced specifically to serve therapeutic purposes, such as Goa Stones.

The published body of research in the form of peer reviewed academic papers and chapters in books, is appended at the end of this thesis and presented in chronological order of publication date. This selection is taken from a broader body of published work, a full bibliography for which is provided in Appendix 1.

A wide range of mineral materials has been considered and a key to those items for which substantial historical comments and analysis have been made is given in Table 1; many other materials are mentioned in passing or cited briefly.

This introduction provides critical and historical context for the publications included in this thesis outlining the probable identities of mineral materials cited in a wide range of sources and the broadly pharmaceutical ways in which they were utilised from classical times to around 1750. This includes their magico-medicinal use as amulets and prophylactics, their traditional medicinal uses as Galenic simples and, with the development of iatrochemistry, the use of their active ingredients and processed derivatives. The outline classification of mineral materials presented above acts as a template for systematic discussion, and this is set against the backdrop of changing fashions and philosophies in the history of medicine. The publications chosen for inclusion in this thesis were selected as covering representatives of the mineral materials presented in the outline classification, a fuller account of which is developed in the body of work detailed in Appendix 1.

1.2 Previous work

Previous research into the historical use of mineral materials in folk medicine and the developing pharmacopoeia is sparse and relatively cursory. The word 'Lithotherapy' was coined by the German physician and pharmacist, Hermann Georg Fühner (1871–1944). Using published lapidaries as his source material, Fühner completed his doctoral dissertation (1902) at the University of Strasbourg on the history of the use of precious stones in medicine. The word has since been

commandeered by New Age beliefs and given to mean the use of the energy emitted by minerals for healing purposes. Relatively little serious research has been completed on the topic of lithotherapy since Fühner's contribution, the literature containing only brief overviews of the subject and mentions of interesting points of information in passing (see Duffin 2013e).

1.3 Historical context

The humoral approach to medicine, dating from Hippocratic times, was championed by Galen and relied upon the philosophical underpinning of Aristotelianism. The medicinal simples from this tradition were later often referred to as 'Galenicals' and were generally administered with very little modification, other than being reduced to a powder (e.g. fossil echinoid spines, belemnites, pumice) and added to other supposedly active ingredients to form a more complex polypharmaceutical preparation. Some were ascribed special powers and 'magnetic' properties (e.g. 'aetites' and a range of fabulous stones believed to be produced or used by living animals). Sympathetic magic was an important component in the thinking represented here, and presented an interpretative challenge to the medieval Church (Rider 2012; Page 2013).

The folklore of these materials and burgeoning Galenical traditions remained unchallenged for one and a half millennia. The scientific revolution (mid-sixteenth century to late eighteenth century) saw the abandonment of Aristotelianism in favour of Neoplatonism. The iconoclastic views of Paracelsus (1493-1541) ushered in the rise of empiricism which placed emphasis on alchemical distillation of the 'essences' of therapeutic simples, close monitoring of symptomatic responses in patients and a reliance on the Doctrine of Signatures (and, to a lesser extent, on astrology, which had become a key component of medicine in medieval times) (Duffin in press a).

The period of time from the mid-sixteenth century to the mid-eighteenth century was marked by conflict between the 'Galenical' and 'Chymical' approaches to medicinal formulation and practice, with the latter gradually replacing the former in both teaching institutions and printed sources (Duffin 2013h). This pattern is effectively portrayed in the various preparations of early modern mineral materials, especially

amber and 'unicorn horn' (Duffin in press a, 2017c), amuletic and prophylactic uses of which were gradually eclipsed by simple preparations for internal and external use as Galenicals. In turn, these simple preparations were succeeded by more complex derivatives of the base material by alchemical means (in the production of oils, balsams, tinctures and powers for example; Duffin in press a). Several late seventeenth and early eighteenth century *materia medica* collections have survived virtually completely intact to the present day (Duffin 2013h); their composition reflects the contemporary transitional stage of the pharmacopoeia, and preserves unprocessed and minimally processed Galenicals, together with alchemically obtained derivatives which were purer, easier to combine with other components, easier to administer and for which a standardised dosage was easier to obtain.

High market demand for some mineral materials resulted in short supply and encouraged the production of fakes, as well as synthetic substitutes (e.g. *Lapis de Goa* and many artificial pharmaceutical 'stones'), especially during the seventeenth century. Overall, the history of mineral materials as pharmaceutical ingredients reflects changing trends right up to the chemical revolution of the 1780's.

1.4 Amulets and prophylactics

In modern usage, amulets are objects to which have been ascribed the power to protect the owner or bearer from some kind of danger or harm. The more classical sense of the word employs amulets as elements of magical power conferring protection on the owner or bearer against supernatural forces, evil, harm or disease (with the added benefit of their aesthetic value); that extended meaning is used here, in keeping with the past uses of various mineral materials. In some instances, the power of amulets to heal was seen as being enhanced by the presence of textual inscriptions added to the housings of the mineral specimen (Roper 2004; Skemer 2006; Rider 2012).

It is not always easy to discern the amuletic or prophylactic use of inorganic minerals, especially gem stones, unless it is clear from supporting documentation or context that they were being worn for more than their aesthetic value. Certainly, in the early modern period particular emerald pendants and rings have been credited

with prophylactic and curative powers against epilepsy, and turquoise rings were worn to provide protection against poisons (Blaen 2017), but the clearest examples of prophylactic and curative use of inorganic minerals come from antiquity. For example, the Assyrians wore beads of lapis lazuli together with a variety of other stones, in order to protect the wearer against various diseases conferred upon them by the 'Hand of Ghost' (activities of dead ancestors), especially intense pain in various parts of the body (Duffin 2014a).

The *Aetites* (the Eagle Stone) has an enormously long folklore pedigree. Usually a nodule of siderite enclosing fragments of clay and sand grains, specimens were worn in silver-clasped mounts and commonly used to control childbirth (Duffin 2012b).

Nephrite jade began to be imported into Britain in quantity from South America in the seventeenth century, with Sir Walter Raleigh advising that it could be used as a type of 'spleene stone'. Often referred to as *Lapis nephriticus*, it was revered as a supposedly effective prophylactic against urogenital disorders, particularly renal calculi; its primary therapeutic virtue was believed to be the magical destruction of bladder stones, so that their remains could be voided both harmlessly and painlessly (Duffin 2006b, 2013h). Indeed, a jade pendant was worn by Christian IV of Denmark (1577-1648) for this purpose throughout his life.

Mineraloids have an especially rich pedigree in this regard, with the organic mineraloid, amber, being a particularly popular material worn for its aesthetic as well as its supposed magico-medicinal properties (Duffin 2008a, 2013d, in press a). In summary, classical references credit amber with the power to protect against diseases of the mouth and throat, as well as against strangury, fevers and the plague. Medieval references add easing childbirth to this list, and in early modern times it was also employed against ocular conditions, cramp, and convulsions. Amber continued to be used in the recent past to aid teething, as well as to treat disorders of the breast, and general ailments.

The inorganic mineraloid, flint, especially examples with natural holes in them (often referred to as 'hagstones'), were occasionally carried about the person or worn as means of protection against the effects of witchcraft, as well as to protect against the ague (malaria) and backache (Duffin 2011a). These were also believed to protect horses against the 'night-mare' (Duffin 2010d).

Biogenic minerals also played an important role in this regard. In the case of fossil sharks' teeth, as well as being worn as amuletic pendants to afford protection against poisoning (Duffin 2017a), specimens were employed as elements of elaborate tableware to detect and neutralise poisons in items of food and drink (Duffin 2012a), as indicated in numerous contemporary papal and royal inventories (Duffin 2017a), and even in works of art (Duffin 2011b). Toadstones were fossil fish teeth which could be set in gold or silver mounts and worn as cabochons in rings or pendants, again, to give protection against and detection of poisons (Duffin 2010a) as well as in the treatment of a range of diseases (Duffin 2008a).

Bezoar stones, concretions formed in the digestive tracts of a range of herbivores, were similarly revered, mounted in specially constructed gold filigree cages or worked as items of tableware to give an additional means of testing for poisons at the meal time, particularly during the seventeenth century (Duffin 2013a). The Porcupine bezoar provides a particularly interesting case history, being used as an infusion to neutralise poisons in wine at the table (Duffin 2013b). Fragments of Narwhal incisor teeth, identified as unicorn horn from at least the eleventh century, were also worn as prophylactic gems (Duffin 2015a) and employed as part of renaissance table preparation and feasting etiquette in order to detect and neutralise poisons (Duffin 2017b, c). Fish otoliths (calcareous gravisensory 'stones' from the inner ear), have been used as amulets from pre-Roman times to the present day. Although now largely seen as 'lucky stones' they were worn as items of personal jewellery in classical times to prevent headaches and, more recently, to ensure good health and both prevent and cure specific maladies such as ear problems, fevers, rheumatism and lumbago (Duffin 2007a, 2016b).

Chelidonius, or the Swallow stone, was tied to the left arm by a linen rag and kept there for three days as a treatment for lunacy, insanity, epilepsy and depression (Duffin 2013c). If the black variety was enclosed in a yellow linen rag, it was believed to be successful in the treatment of malaria, fever and tumours. *Chelidonius* was also placed under the eyelid to cure all sorts of ocular conditions. It was also used amuletically to cure various types of malaria, fever, tumours, typhus, sores, and to avoid stillbirth (Duffin 2013c). Like *Chelidonius*, the Ostrich stone was used in cases of ophthalmic diseases, but details of its application are lacking (Duffin 2012b).

Zahir mora, a stone said to be harvested from the head of the Adjutant Stork, was applied to wounds and snake bites in the belief that it could remove any poison. Having completed its job, the stone was soaked in milk in order to extract the accumulated toxins so that, fully cleansed, it could be used again (Duffin 2012b).

Fossil corals, especially those collected from rocks of central Italy, were worn as 'witchstones' to protect against the Evil Eye and supernatural attack (which could result in illness), as well as supposedly ridding the wearer of intestinal worms (Duffin in press b). A number of other fossils including brachiopods, ammonites and belemnites were also worn as amulets, especially in the Alpine region, but it is currently not clear what benefit was supposedly conferred upon the bearer (Duffin in press a). Good health was also ensured in Sussex, England by wearing a necklace of beads made of the fossil sponge, *Porosphaera*; such necklaces date from the Bronze Age to the early twentieth century (Duffin 2011a).

1.5 Galenical simples

Claudius Galenus of Pergamon (129 - circa 216) was a highly influential Greek physician, philosopher and medical scholar who studied in the medical school at Alexandria, following and developing Hippocratic teachings while he was physician to the gladiators at Pergamon, and later as a practising physician in Rome (Mattern 2013). He wrote extensively; it has been estimated that his works represent almost half of the surviving literature of ancient Greece, and that what survives probably represents only a third of his actual output (Kotrc & Walters 1979; Ustun 2004). The collapse of the western Roman Empire in the Early Middle Ages and, with it, the Greek medical tradition, threatened the loss of Galen's writings as few western Latin scholars could read Greek. Fortuitously, however, extant manuscripts of Galen's works were copied by Byzantine scholars and became available to the increasingly important world of Arabic Muslim scientific research, largely through translations into Arabic by Syrian Christian scholars. Indeed, some of Galen's works are still available only in Arabic. A further programme of translation, this time from Arabic copies into Latin, took place at dedicated translation centres and scriptoria, particularly in Italy and Spain, during the twelfth century. In this way, Galen's

works and his philosophy of medicine (Galenism) were rendered newly accessible to the West, quickly becoming incorporated into university curricula and assuming almost unassailable authoritative status. An insight into the materials utilised by Galen can be seen by consulting his *De simplicium medicamentorum temperamentis ac facultatibus*, parts of which were translated into Syriac by Sergius of Reshaina (died 536), and from Greek into Latin by Theodoricus Gerardus Gaudanus (Thierry Gheeraerds di Gouda) in 1530.

One of the Greek predecessors of Galen and referred to by him, was Pedanius Dioscorides (circa 40 – 90), a physician famous for his *De Materia Medica*, a five volume compendium of contemporary herbal and other therapeutic substances which, unlike many of the works of Galen, was continuously available to Western scholars. Geological materials appear in Book 5 of Dioscorides' work, with wines and metals included in the same section. There are 99 items listed and detailed in the section on metals and stones (although some items are clearly not geological in origin). The high degree of consonance between the geological materials listed both in Dioscorides and Galen, indicates that mineral materials were well established contemporary medicinal simples and legitimately counted amongst the 'Galenicals' of later authors.

Rock samples falling into this category of geopharmaceutical include lapis lazuli, slate, pumice and *terra sigillata*. The extrusive volcanic rock pumice was used primarily as an abrasive, being employed since classical times as a depilatory (to remove hair from the skin), cicatrizing (wound-healing by scar formation) agent, cleanser for teeth (dentifrice), gums and skin, and the means by which corneal ulcers and various growths could be removed from the body surface (Duffin 2013g). It was also used as a sternutatory (to provoke sneezing) and in the treatment of ringworm. Traditional Chinese Medicine saw it being used, together with other materials, to treat anxiety disorders, as well as a variety of urogenital conditions (Duffin 2013g).

Terra sigillata are round cakes of compressed medicinal earth, usually formed from residual clays and often made up of smectite clay minerals. The most famous examples come from the Greek island of Lesbos (Lemnian earth, *Terra Lemnia* or *Sphragides*), where mining in classical times followed ritualistic oversight and the

end product was authenticated by means of surface stamps giving an embossed surface on the upper side. The stamp or seal was a mark both of genuine quality and provenance, and gave rise to the generic term '*terra sigillata*' (sealed earth) for this type of medicinal troche, which was then the subject of a thriving export market. Other significant sources of *terra sigillata* included the Mediterranean island of Malta; following his shipwreck on the island in 64 AD, St Paul was welcomed by the locals and according to legend, was housed in a grotto at Rabat, now under the foundations of St Paul's Church. According to Maltese folklore, the presence of St Paul on the island resulted in many of his body parts becoming represented by structures entombed in the local rocks. The power and erudition of his preaching and teaching supposedly invested the rock of the grotto walls with great sanctified healing power. It was accordingly mined, fashioned into lozenges, sealed and exported as *terra sigillata melitensis*, also known as St Paul's Earth. A third important source was discovered and exploited in western Poland during the sixteenth century as *terra strigonensis*. These, and other, medicinal earths were widely used as alexipharmics to counter the actions of poisons, whether ingested in the diet or due to infection, and are commonly represented in surviving *materia medica* collections (Duffin 2013h). *Terra strigonensis* supposedly exhibited similar therapeutic properties to those credited to unicorn horn, and was often marketed as mineral unicorn horn (Duffin 2017c)

A rather peculiar survival of the use of rock material (this time in the form of a powder), with its therapeutic virtues enhanced by Christian religious associations, is represented by rock flour scraped from the walls of churches and cathedrals, particularly in Germany, the Netherlands and Belgium (Weertz, Weertz & Duffin 2014). In an interesting range of variation, therapeutic sands and powders were obtained by digging samples from Christian sites of pilgrimage, cemeteries, from beneath the statues, tombs and graves of certain saints, through to working chips and scrapings of material from the outer and inner walls of older churches. The religious potency of the material was sometimes enhanced by ensuring collection at specific times of festival in the Christian calendar. Once obtained, these samples of magico-medicinal stone powder from consecrated sites were mixed with cattle fodder to ensure the health of the herd, as well as being administered to human patients, usually in a suitable draught, in order to treat urogenital disorders, plague, fevers,

toothache, headache, warts and a range of other disorders (Weertz, Weertz & Duffin 2014).

Lapis hibernicus, or Irish Slate, was esteemed in early modern times as a styptic (causing constriction of the blood vessels), and hence used to treat bleeding associated with all sorts of conditions – wounding, excessive menstruation and haemoptysis (coughing up of blood). By association, it was also deemed good for conditions of the lungs and bruising. It was most commonly taken as a powder dispersed in 'spruce beer' (Duffin 2013h).

A wide range of non-biogenic minerals has been employed as Galenical simples from classical times through to the eighteenth century. The rationale for their use is not always obvious and often probably stems from local medical folklore and oral traditions. In some cases, however, it is possible to identify the principles of sympathetic magic at work, especially *similia similibus curantur* ('like cures like') and the closely related Doctrine of Signatures (Durant 2017). The latter concept extends back to classical times, but came into its own during the fifteenth and sixteenth centuries; it is often referred to in works considering the evolution of the pharmacopoeia, especially in relation to herbal simples, but still awaits serious scholarly treatment, especially in respect of pre-fifteenth century literature and writings. In essence, the Doctrine of Signatures states that the outward appearance of (usually) a plant possesses a certain stamp or *signatum* of God's handiwork revealing, usually by correspondence of form, colour, smell or other quality, what medicinal, therapeutic benefit that plant might provide (Duffin in press a). The Renaissance alchemist and iconoclast, Paracelsus, explained the Doctrine in this way (Hartmann 1896:55) :

> The soul does not perceive the external or internal physical construction of herbs and roots, but it intuitively perceives their powers and virtues, and recognises at once their *Signatum*. This signatum is a certain organic or vital activity, giving to each natural object a certain similarity with a certain condition produced by disease, and through which health may be restored in specific diseases of the diseased part. This signatum is often expressed even in the exterior form of things, and by observing that form we may learn something in regard to their interior qualities, even without using our interior sight.

Paracelsus perceived this type of correspondence to be one of the secrets of nature, and went so far as to say that no person could be a successful doctor unless he was able to discern these various signs (Hartmann 1896:55) :

> I have reflected a great deal upon the magical powers of the soul of man, and I have discovered a great many secrets in Nature, and I will tell you that he only can be a true physician who has acquired this power.

Giving the example of St John's Wort, he writes :

> I have ofttimes declared, how by the outward shapes and qualities of things, we may know their inward virtues, which God hath put in them for the use of man. So in St Johns Wort, we may take notice of the leaves, the porosity of the leaves, the veins. The porosity of holes in the leaves, signifies to us, that this herb helps inward or outward holes or cuts in the skin.... The flowers of Saint Johns Wort, when they are putrified they are like blood; which teacheth us, that this herb is good for wounds, to close them and fill them up. (Paracelsus 1656:122).

The Doctrine was also applicable to geological materials, although some associations are much clearer than others. The iron oxide mineral haematite, for example, has a cherry-red streak (indicating the colour of the powdered mineral) which evokes the colour of blood. In consequence, it is one of a group of materials which were collectively referred to as 'bloodstones', and it was recommended in the treatment of blood-shot eyes, excessive menstrual flow and, in conjunction with other blood-red simples, to treat dysentery ('the bloody flux'), nosebleeds and other haemostatic conditions (Duffin 2013h).

Selenite, a variety of the calcium sulphate mineral gypsum, was supposedly identified on the basis of the figure of the moon which it appeared to possess. The figure supposedly went through cycles of waxing and waning fully synchronised with the phases of the moon. Consequently, the mineral was used to treat epilepsy, which was thought to be governed by the Roman goddess Selene, who controlled the lunar cycles which caused perturbations in the human mind (Duffin 2013h).

Other examples of mineral galenicals include pyrite (iron sulphide) which was used to treat diarrhoea, garnets which were used to lift the spirits, and *Crystallus* (Rock

crystal or quartz) which was believed to encourage lactation, as well as being used in the treatment of dysentery, bladder stones, fevers and vaginal discharges (Leucorrhoea) (Duffin 2013h). Cinnabar, the common ore of mercury, went through a steady evolution of medicinal application, progressing from being used as a worming agent in sheep, to being similarly applied to children, through acting as a parturient (promoting birth) and then an abortifacient (to encourage miscarriage) in women (Duffin 2013h).

Lapidaries, or books about stones, are sometimes rich sources of information about the historical pharmaceutical uses to which various minerals were put. The thirteenth century Lapidary of Sidrac, largely overlooked with respect to the pharmaceutical lore which it contains, furnishes a good example. Twenty four stones are listed in the Lapidary, for twenty of which some pharmaceutical folklore is listed (Duffin 2015c).

Inorganic minerals were sometimes used in conjunction with each other, and with herbal and zoological simples. One compound medicine or polypharmaceutical which enjoyed much popularity and a long history of use was the gem electuary (Duffin 2013f). The original recipe for this preparation was proposed by the eleventh century Arabic doctor Mesuë the Younger (also known as Pseudo- Mesuë, Maswijah al-Marindi or Johannes Mesuë of Damascus). It included a number of geological ingredients – sapphire, hyacinth (red zircon?), emerald, garnet, amber, gold, silver and chalcedony – which were pulverised and mixed with a range of finely ground animal and botanical ingredients to form a medicinal paste. The recipe for the electuary evolved over time, as different authorities replaced difficult-to-find ingredients with locally more readily available substitutes, and incorporated the receipt into various pharmacopoeias and compilations. The electuary was used as a therapy in its own right, but was also sometimes combined with other polypharmaceutical preparations to produce highly complex mixtures with a great deal of intrinsic redundancy, as many ingredients were duplicated as a result of combining the recipes. The resulting mixture was used to treat an enormous range of diseases including melancholia, nightmares, plague, syphilis, palsy, cramp, breast cancer, headache, erysipelas, fevers, tuberculous adenitis (scrofula) and a range of

gynaecological conditions, as well as being employed as an alexipharmic and cardiac tonic. Usually taken internally, it was also applied topically with the apparent added benefit of being a rubefacient (making the cheeks rosy) and fragrant cosmetic.

Only the organic mineraloids were popular as Galenic simples. Jet, a lignitised driftwood famously found in the Jurassic deposits of the Whitby area of England, was used to treat tooth ache and scrofula (tuberculosis) in Roman times, and burnt to provide a purging smoke which would supposedly encourage onset of menstruation. The rather similar Cannel Coal (also known as Sporinite – a sapropelic coal) was used to treat colic (Duffin 2013h).

The fossil resin, amber, was enormously popular as a Galenical, with a huge range of applications for a multitude of diseases, and applied by means of a sometimes inventive set of delivery systems. The Tertiary amber deposits of the Samland Peninsula and other localities along the southern and south eastern Baltic coast were the main source of supply of medicinal amber from antiquity onwards. Amber contains the physiologically active ingredient, succinic acid, and is found in a variety of colours and states; white amber, containing large numbers of trapped air bubbles, was commonly perceived as the most desirable variety for pharmaceutical purposes. Galen recommended working amber, together with a series of other ingredients, into several types of lozenge which could then be taken for a range of respiratory and digestive complaints, and rheumatism (Duffin 2008a). The recipes for Galen's lozenges were taken up by numerous subsequent classical physicians, and their range of application occasionally modified. The burning of amber produced fumes which could then be inhaled or used as a fumigant to treat epilepsy and manage a range of obstetrical and gynaecological conditions (also by means of amber-containing pessaries) (Duffin 2008a). Breathing in amber fumes from specially designed quilts and pillows was also believed to strengthen the body, and to be valuable in maintaining health (Duffin 2013d). Topically, amber was applied to the skin surface as one of a mixture of materials in plasters, ointments, balsams and poultices in the treatment of wounds, sciatica, gout, scurvy, broken bones, bruises, syphilis, as well as in a bid to control the flow of various 'defluxions' or discharges (Duffin 2013d). Finely ground amber was added to a range of therapeutic powders

which could be taken by the patient in a suitable draught of wine, sack or milk in the treatment of a wide range of diseases including melancholia, smallpox, measles, plague, epilepsy, fevers and gynaecological disorders (Duffin 2015b). Incorporated into medicinal pastes or electuaries, ground amber was also used as a haemostatic in order to help manage various bleeding disorders, such as haemorrhoids, dysentery (bloody flux) and excessive menstrual bleeding. Amber could also be taken in a wide variety of pills, tablets, troches, fluids, lohochs ('lick pots' or linctuses), as well as on medicinal toasts and with poached eggs (Duffin 2015b). By these means, the mineraloid was used to treat various vascular disorders (e.g. haemoptysis, haemorrhage, excessive menstrual bleeding); problems with the urogenital system (e.g. tendency towards miscarriage, impotence, venereal diseases, strangury, dysuria and bladder stones); alimentary conditions, particularly dysentery; a variety of infectious diseases, including plague, gonorrhoea, measles and fevers; and the ravages of old age. Rather more unusual applications included its use in the treatment of impotence, halitosis, drunkenness and a weak back (Duffin 2015b). Amber is a common component of surviving *materia medica* cabinets from the early eighteenth century (Duffin 2013h).

Biogenic minerals from the bodies of extant organisms have an extensive history of use as medicinal simples, and include such popular items as crab's claws (*chelae cancrorum*), 'crab's eyes' (*oculi cancrorum* – pre-moult gastric growths in astacid crayfish), and ivory. Narwhal ivory obtained from its elongated incisor tooth was identified as unicorn horn from at least the twelfth century, and at least some of the material sold as unicorn horn in late medieval and renaissance apothecary shops must have been narwhal horn. Belief in the legendary unicorn with its highly therapeutic, alexipharmic horn was bolstered by the Christian Church which used narwhal horns as processional staffs, kept horns with one end soaking in water (for the sick to drink) near the altar, and provided the animal with scriptural authentication in the Latin translation of the Bible, and the English translations derived from it. The unicorn became an allegorical symbol of Christ in the medieval bestiaries, and horns were available at great cost from trade with northern merchants. Segments of Narwhal horn were hollowed out and fashioned into goblets; wine poured into or stored in these unicorn horn cups was supposedly cleansed of any poison by the antitoxic properties of the horn. Smaller chips of horn could be used

as testing agents by dipping them into beverages before they were made more generally available at the table. Powdered horn could be combined with myriad other components and used to treat an enormous range of diseases including rabies, plague, digestive ailments, fevers, smallpox, measles, and respiratory problems. Water in which unicorn horn had been soaked was administered to treat scurvy, ulcers, gout, epilepsy, rickets and a range of other diseases. It could also be administered in cordials, electuaries, conserves and confections (syrupy drugs) (Duffin 2017c).

An alternative to Narwhal horn was provided by *Unicornu fossile* or fossil mammoth ivory, believed by some to be the 'true' unicorn horn, since it clearly came from a terrestrial animal, being dug from the earth. This too, was esteemed good for stomach complaints, and used in cases of poisoning, fever, heart problems, epilepsy, syncope, worms, excessive bleeding, syphilis, and gonorrhoea, as well as cicatrising weeping ulcers and open sores (Duffin 2017c).

Both Narwhal horn and mammoth tusk are composed of the mineral apatite, a hydrated calcium phosphate. Further fossil sources of this mineral were available in the form of Bufonites or *Lapis Bufonius* (the Toad Stone) and *Glossopetrae* (Tongue Stones); these can be identified respectively as the crushing teeth of Mesozoic bony fishes such as *Lepidotes* and *Scheenstia*, and fossil sharks' teeth. The hemispherical morphology of Toad Stones, by the Doctrine of Signatures, showed correspondence with the 'warty' epidermal parotid glands on the back, neck, shoulders and head of the toad. These glands, which may be single or aggregated into multiglandular units, synthesise and store a range of alkaloids, some of which may be highly toxic, and which act as antipredatory and antimicrobial chemicals. The poisonous nature of the toad's dermal secretions meant that the Toad Stone was credited with alexipharmic and antitoxic virtues. Swallowing the Toad Stone whole was believed to mitigate a range of digestive disorders, as well as removing the poisons associated with tumours, erisipelas, fevers, sores, abscesses, malaria, plague, carbuncles, diarrhoea, epilepsy, bladder stones, fits, and helping to ease labour pains (Duffin 2008a, in press b).

The Doctrine of Signatures was also obvious in the use of *Glossopetrae*. The commonest type of fossil sharks' tooth identified as a Tongue Stone was the large, triangular tooth of *Otodus megalodon* from Tertiary rocks. This was believed to be shaped like a tongue. The bilobed root of complete specimens evoked the divided distal part of a snake's tongue, and other specimens were supposedly shaped like the tongues of woodpeckers, otters and even mankind. The association with the snake indicated that the teeth should be utilised with respect to poisons, as indicated above in the section on amulets and prophylactics. Powdered, they were also incorporated into Mesuë's gem electuary, according to some recipes (Duffin 2013f), as well as being the subject of a special decoction on Malta (Duffin in press b).

In addition to the unicorn and the toad, magico-medicinal stones were believed to be present in the bodies of a range of other extant and mythical creatures. Birds have a particularly rich associated medical folklore in this regard. One of the most popular of these was *Alectorius*, a stone obtained from castrated male chickens or capons. Contemporary reports vary as to the site in the body from which the stone was harvested (Duffin 2007b; Carrasco & Duffin 2017), although the two main hypotheses as to its origins are (1) an ingested stone (gastrolith) swallowed in order to provide a triturating aid to digestion, (2) a biliary calculus. In addition to conferring various desirable personal qualities to the bearer, ensuring success in battle and enhancing athletic prowess, *Alectorius* was reported to ease thirst (as in quite a wide range of other sialogoguic stones), to increase fecundity, promote lactation and ease childbirth, whether drunk in powdered form in a suitable draught, or worn as an amulet. It was also commended against heartburn and abscesses, as well as being used to prevent scabbing in sheep (Duffin 2007b).

Zahir mora (Adjutant Stork stone, but possibly a type of bezoar) was, according to medieval Islamic medical tradition, powdered and administered in a healing draught to treat palpitations of the heart. A modern unanipathic derivative of this approach utilises this stone as part of a cardiac tonic (Duffin 2012b). Pigeons were also believed to be the source of medicinal stones (*Lapis palumbellarum* – probably gastroliths), this time administered in a draught combined with certain flowers, and used to treat kidney stones (Duffin 2012b).

A number of fossil invertebrates possess calcareous shells (made of calcium carbonate): *Lapis judaicus* (the Jews' Stone) consists of the spines of fossil echinoids (sea urchins), particularly *Balanocidaris* sp. from Mesozoic rocks; *Lapis lincis* or *Lyncurium* (the Lynx Stone) was represented, at least from the sixteenth century onwards, by fossil belemnite rostra. Both *Lapis judaicus* and *Lapis lincis* have enormously long pedigrees as Galenic simples, being first referred to in classical literature and having a period of use up to around 1750. Also, both items have fairly clearly defined medicinal applications determined by the Doctrine of Signatures. The echinoid spines were described as having a phallic shape and were consequently used primarily to treat urogenital problems, particularly bladder stones. *Lapis lincis* was believed to be formed from congealed lynx urine, and reportedly smelled of such on being broken; they, too, were therefore utilised for urogenital problems. Many of the echinoid spines which entered western apothecary shops were exported from the Mount Hermon region of what is now Lebanon, having been collected from the Late Jurassic rocks exposed there. The stone was either sucked whole or ground into a powder for dispersal in a suitable liquid medium in order to disperse stones in the bladder (Duffin 2006a, 2006b). It was also one of the components which the twelfth century physician and philosopher Maimonides recommended for inclusion in a special plaster designed to counteract the poison in snakebites by being laid over the wound (Duffin 2008). Medicinal echinoid spines are still available today in a range of Middle Eastern bazaars (Duffin 2008).

Hildegard von Bingen, a twelfth century German Abbess, recommended Lynx Stones soaked in a suitable medium for the treatment of chronic stomach-ache and painful, difficult urination (perhaps due to hypertrophy of the prostate gland). It was also commended in cases of jaundice, malaria and haemoptysis, and was esteemed as being able to reduce the incidence of stillbirth and the effects of poisoning (Duffin 2006b, 2008). The lynx was believed to possess miraculous powers of sight, being able to spot potential hunters at impossible distances and even to see through solid rock. As a consequence, the Lynx Stone, together with other parts of the animal, was credited with therapeutic efficacy in conditions of the eye (Duffin 2008). Both *Lapis lincis* and *Lapis judaicus* are common components of surviving early modern medical cabinets (Duffin 2013h).

Although based on a different philosophical system (Duffin 2013e), fossils in relatively unmodified form are a significant part of Traditional Chinese Medicine both today and in the past (as far back as the second millennium BC). Pleistocene fossil crabs, for example, were used to treat ocular and uterine problems, ammonites were employed as alexipharmics in cases of metal poisoning, 'dragon' bones and teeth (usually fossil mammal remains) were incorporated into numerous decoctions and mixtures, and fossil brachiopods were commended for rheumatism, skin diseases and arthritis (Duffin 2012b, in press a).

Bezoar stones were highly popular medicinal components, particularly as alexipharmics in the sixteenth and seventeenth centuries. Porcupine bezoars, obtained from Borneo, Sumatra and the Malay Peninsula, were used to produce an infusion which was credited with the power to cure cholera, as well being prescribed to induce a mitigating sweat in cases of plague. It was hailed as something of a cure-all, being recommended for kidney stones, pleurisy, fevers, palpitations of the heart, epilepsy, intestinal worms, the bloody flux (dysentery), colic, flatulence, poisoning, internal abscesses (apostems), stomach pains, intestinal obstructions, jaundice and chicken pox (Duffin 2013b).

Otoliths from a range of common food fishes have been credited with therapeutic properties since Roman times. In folk medicine, they were employed in the treatment of renal problems, malarial fever, nose bleeds, jaundice, pain, and swellings in the groin. They were also believed to act as aphrodisiacs. Modern applications include the treatment of urinary tract infections in Turkey, fever in Spain, and asthma and back pain in Brazil (Duffin 2007a). Recorded under a variety of names (e.g. *Cinaedia, Asellus, Bacchus, Lapis Carpionis, Aquilinus, Coracinus* etc) they are common components of historical *materia medica* collections (Duffin 2007a, 2013h).

1.6 Iatrochemical preparations

A revolution in scientific thinking and methodology took place in rather a stochastic fashion from the early sixteenth century onwards (Burns 2016), culminating in the chemical revolution usually pinpointed as occurring in 1786 with the work of Lavoisier. The Aristotelian underpinnings of Galenism were the first things to come under attack. The works of Aristotle were translated into Arabic during early medieval times and were later made more fully available to the west in the programme of translation of scientific works from Arabic into Latin during the twelfth century. The principles of Aristotelianism embodied in the philosophical works of Aristotle and his commentators became part of the university curriculum and universally revered. Despite the efforts of Albertus Magnus and others to syncretise Aristotelian teaching with Christian philosophy and its uptake by the Catholic Church, there was no getting around the fact that Aristotle was a non-Christian, and so was Galen, who uncritically followed Aristotle's work. Indeed, Bostocke (1585, unpaginated) wrote that 'the heathenish Phisicke of Galen doth depende upon that heathnishe Philosophie of Aristotle, (for where the Philosopher endeth, there beginneth the Physition) therefore is that Phisicke as false and injurious to thine honour and glory, as is the Philosophy', concluding that Galen was 'that heathen and professed enemy of Christ'. John Webster (1654:73) observed that Galen was 'an ignorant Pagan who .... did traduce and darken the writings of those that preceded him'. Francis Bacon called Galen 'that narrowest of minds' in 1605, and laid the blame for the stultification of medical progress firmly at the feet of those who followed Galen's teachings without thinking for themselves.

The Italian humanist philosopher, Marsilio Ficino (1433-1499), led the challenge to release the grip of Aristotelian philosophy on the natural sciences, instituting a movement which came to be known as Hermetic Platonism or Neo-platonism. Based on some of the writings of Plato, Ficino and his followers expanded the idea of the microcosm and macrocosm in which body and soul were seen as miniature replicas of the body and soul of the world. Between these two, mankind and the world, correspondences, sympathies and antipathies supposedly ruled in interactions which

only a magus could interpret, understand and exert any control over (Duffin in press a).

The Swiss physician Philip Theophrastus Bombast von Hohenheim (1493-1541;), also known as Paracelsus, took this idea even further, expressing his view in the well-known dictum 'As above, so below'; cosmic design had made man a mirror of the universe. The important implication for Paracelsus of this correspondence between microcosm and macrocosm was that processes observed in the outer realm could be identified in the human body and applied to its physiology; God created man in his own image, but he also created the universe in the image of man (Duffin in press a). Furthermore, the loving benevolence of God meant that he left his signature everywhere so that mankind would be able to recognise his handiwork and apply it to his benefit. Thus, the Doctrine of Signatures took on new importance; the inherent virtues and medicinal properties of plants, animals and geological materials could be determined from their external appearance. The virtue itself, however, was seemingly hidden inside the material and needed to be released in order to harness its therapeutic power and potential. This seemed to Paracelsus to be a far more sensible approach to healing than the bleeding advocated by the followers of Galen, and the production of complex mixtures of material formulated to somehow readjust the balance of humours. Whereas Galenical mixtures could be perceived somewhat as cure-alls, being applied to a whole range of diseases which supposedly resulted from humoral imbalance, Paracelsus considered that the natural virtues, once released from the parent material, could be used to target individual diseases. The various means of separating the active principle from its parent material were the alchemical processes of distillation, sublimation, solution etc. – all fairly standard techniques developed since Egyptian times. The adoption and development of this approach by the enthusiastic followers of Paracelsus led to the development of iatrochemistry or medicinal chemistry (Duffin in press a; Debus 2003). Advantages of the method related mostly to quality control; chemical extracts would be less likely to be tainted by impurities, allowing much more careful standardisation of dosage.

Mercury is a metal that has been utilised medicinally, in various forms, since classical times. Initially, untreated cinnabar (*cinnabaris nativa*), the commonest of the ores of mercury, was the means of administration. As can be imagined, however, the grade of the ore and consequently the volume of mercury in relation to gangue must have been highly variable. Heating the ore released the liquid mercury, however, which could then be mixed with sulphur, cooled and reduced to a powder. On slow reheating and careful cooling, a purer more concentrated crystalline form than the initial ore was produced, going under the name *cinnabaris factitia* (Duffin 2013h).

Of all the geological materials to undergo alchemical processing, amber was the most popular and versatile. Lumps of raw amber were loaded into a glass retort or alembic and heated. By fractional distillation different volatiles were liberated at different temperatures. These could then be distilled by condensation in a receiver or cucurbit to produce Oil of Amber (*Oleum succini*), leaving progressively thicker residues in the alembic. One particular late-stage fraction was sublimated on the neck of the retort (*Sal succini* or Salt of Amber). The Oil of amber could be heated and distilled further (the process of rectification) to yield a more purified oil, with the residue in the retort referred to as Balsam of Amber. Dissolving amber or its alchemical derivatives in ethanol (Spirit of Wine) resulted in the Tincture of Amber (*Tinctura succini*). Processed in this way, it became relatively easy to add regulated amounts of amber derivative to mixtures of drugs; it also made it possible to apply the material to the skin surface (Duffin 2008, in press a).

Salt of Amber was prescribed for nervous and 'hysteric' complaints and Oil of Amber, which was apparently a very disagreeable medicine to take, was, in addition, given in cases of scurvy, convulsions, apoplexy, epilepsy, plague, paralysis and many further complaints. Tincture of Amber was employed for a similar range of conditions (Duffin 2008, 2013h).

Jet has been utilised to produce an oily distillate since the eleventh century. Mesuë indicated that a descensory furnace should be used to produce the oil, which was then used to maintain generally good health and to treat epilepsy, paralysis, nervous spasms, tetanus, arthritis, and *globus hystericus* (Duffin in press a).

Lapis judaicus and *Lapis lincis,* once finely powdered, could be heated with sulphur until the mixture was red hot. After having been allowed to cool, the material was finely powdered and dissolved in Vinegar and Hydrochloric Acid (Spirit of Salt). Further processing resulted in fine crystals which were recommended in medicines for urogenital conditions, particularly bladder stones (Duffin in press a).

In addition to these various treatments of mineral materials to release their inherent active principles in salts, oils, balsams and tinctures, a whole suite of synthetic pharmaceutical 'stones' appeared in the apothecarial market place early in the seventeenth century; some were to become officially accepted by the medical community and included in official pharmacopoeia, while others were the work of quacks and mountebanks. With soaring demand for authentic bezoar stones, the market was plagued by limited supply, and many of those that were being sent to the West from India and elsewhere were of inferior size and quality. A number of artificial stones was developed, either as direct substitutes or alternatives to true bezoars, or were named on the basis of having similar supposed therapeutic effects as them. The most famous and extensively used of these was the Goa Stone (*Lapis de Goa*) which was invented by a Jesuit missionary priest working in Goa toward the end of the seventeenth century. The Goa Stone consisted of a mixture containing musk, oriental bezoar, ambergris, red and white coral, emerald, topaz, ruby, sapphire, jacinth, small pearls, fossil shark's teeth, *terra sigillata*, stones from Cananor and calcined deer horn (Duffin 2010b). The choice of materials was made in order to replicate the therapeutic properties of bezoars and, by means of synergistic reinforcement, even to exceed them in both scope and efficacy (Duffin 2010b). The confection was rolled into spherical balls, coated with gold leaf and, duly authenticated, polished ready for export to Lisbon and the European markets, as well as the Orient. Like true bezoar stones, specimens of *Lapis de Goa* were often

kept in elaborate filigreed silver and/or gold containers. Although supposedly a secret recipe, variants were published in later pharmacopoeia. The stone was used extensively in England to treat a wide range of diseases (Duffin 2010c; Duffin & Pymm 2015a). In addition, two types of Mineral Bezoar were developed as bezoar substitutes; one was a naturally occurring Sicilian stone used at the time to treat smallpox, fevers and worms, while the other was a strong diaphoretic (perspiration inducer) based on Butter of Antimony (antimony trichloride) (Duffin & Pymm 2015a). *Bezoar Joviale* and *Bezoar Lunale* were similarly based upon antinomy and other metals, and taken in order to promote sweating.

Stones being sold by Mountebanks and quacks have their details limited to name and application on the flyers they used to promote their wares (e.g. Moraccolocius, Safonya, Amothist and Safara Stones) (Duffin & Pymm 2015a). The late seventeenth century *Lapis Contrayerva* was based upon one of the New World species of the plant *Dorstenia*, and used as an alexipharmic.

Some artificial stones were, in good Paracelsian fashion, designed to treat a single disease (e.g. the antinomy-based Treacle Stone, *Lapis salutis* for ulcers, *Lapis divinus* for eye problems, and Geoffroy's Stone for battle wounds), while others were more like cure-alls (e.g. *Lapis mirabilis*, the Wonderful Stone and *Lapis medicamentosus*) (Duffin & Pymm 2015a, b).

2. Conclusions

Historical ethnobotanical, and to a lesser extent ethnozoological components of the *materia medica* have formed a major focus of research into the development of the pharmacopoeia (e.g. Lev 2007; Dendle & Touwaide 2015; Amar & Lev 2016). Mineral materials, especially those of geological origin, have received very little consideration by comparison. The body of work presented here seeks to redress the balance by examining the roles played by mineral materials in the evolution of the

materia medica since antiquity. The choice of mineral materials utilised for medicinal purposes in the past is very diverse, ranging from exotic, often hard to obtain specimens of gems and semiprecious stones, to relatively common materials. Some of the more unusual components consist of fabulous stones derived from mythical animals, and novel synthetic and artificial stones invented by the apothecary.

The history of the use of geopharmaceuticals exemplifies the changes taking place in prescribing practice which, in turn, reflect fluctuations in the availability of raw materials, differing degrees of access to relevant classical literature, the impact of technological innovations such as printing and developing alchemical techniques, and the changing background of human society and education with its evolving ideas and intellectual fashions.

3. Assessment of impact

The academic impact of the work I have completed on the historical roles of mineral materials in the development of the *materia medica* can be summarised in the following :

(1) Publication – acceptance of the work for publication in a range of high status peer-reviewed journals, especially the Special Publications of the Geological Society of London, Folklore and Pharmaceutical Historian.

(2) Referencing – in spite of the fact that this is a new research field, currently with few published contributions, my publications have been cited by numerous authors, other than myself (e.g. Barroso 2013, 2014, 2017; Liñan et al., 2013; Carrasco & Liñan 2013; Rolfe 2013; Hoch 2013; Harris 2016) (see Table 2).

(3) Online consultation of publications – those publications which I have been able to post on personal webpages with Academia.edu and Researchgate have been consulted on thousands of occasions (see Table 2).

(4) Teaching – I was asked to speak on Chemistry, Geology and Medicine for classes in the Diploma in the History of Medicine of the Worshipful Society of Apothecaries, a duty which I have carried out for three consecutive years.

(5) Lectures – I have received numerous invitations to lecture on the topics represented in my body of published work to local geological, natural history and national medical and jewellery history societies including :

a. 'Geology and Medicine' to the Hastings Geological Society, Ravensbourne Geological Society, Amateur Geological Society and Hertfordshire Geological Society;
b. 'Fossils as Drugs' to the Royal Institution, Amateur Geological Society, Ravensbourne Geological Society and several others;
c. 'Geological Therapies : A History' to the Grupo dos Amigos do Museu Nacional de Arqueologia, Lisbon;
d. 'Magical and Medicinal Minerals' to the Horsham Geological Field Club;
e. 'Mediaeval Minerals' to the Friends of the Natural History Museum;
f. 'Medicinal Gems : Animal and Antidote' to the Society of Jewellery Historians;
g. 'Minerals and Medicine' to The Russell Society;
h. 'Tales from the Apothecary's Chest' to the Portuguese Medical Association.

(6) Conferences – my research has been accepted for presentation at history of medicine and pharmacy conferences, including the following :

a. 'A history of the Jews' Stone' at the Iraqi Geological Union conference, Baghdad, 2016;
b. 'The medicinal use of Unicorn Horn', British Society for the History of Pharmacy Conference 2014;
c. 'Apothecarial alicorn : symbol and simple' at the conference entitled *Bezoar e Unicorno*, held at the Pharmacy Museum, Oporto, 2012;

d. 'Some surviving late 17th and early eighteenth century materia medica cabinets', BSHP Conference, 2013;
e. 'Amber as a component of Palaeontological Pharmacology', Amber in the History of Medicine Conference, Kaliningrad, 2015.

(7) The following posters have also been presented at these and other conferences and symposia :

a. 'Rocks in the Garden of Health : De lapidibus in Hortus Sanitatis (1491)';
b. 'Geological Prophylactics in Petrus Christus' Painting : A Goldsmith in his shop, possibly Saint Eligius (1449)';
c. 'Hortus Sanitatis : The Garden of Health'; 'The Materia Medica Collection of John Burges (1745-1807) in the Museum of the Royal Pharmaceutical Society';
d. 'The Pharmaceutical use of Lapis Lazuli'; 'Historical sources of therapeutic stone powder from Europe';
e. 'Bezoar stones and their contents'; 'History of the Jews' Stone (Lapis judaicus)';
f. 'Magico-medicinal minerals in the Lapidary of Sidrac (thirteenth century)';
g. 'The medicinal use of unicorn horn';
h. 'The gem electuary'; 'The medical use of unprocessed amber'.

(8) Invited speaker – I have been asked to give Keynote addresses to specialised conferences on the history of medicine in Lisbon and Kaliningrad.

(9) Symposia – I have been asked to help organise conferences on aspects of the history of Geology and Medicine by the History of Geology Group of the Geological Society of London (2011 and 2014), and the Amber Museum in Kaliningrad, Russia (2015, 2017).

(10) Books – I have been asked to act as Corresponding editor for two books on aspects of the history of Geology and Medicine (Duffin, Moody & Gardner-Thorpe 2013; Duffin, Gardner-Thorpe & Moody 2017). I have also been invited to contribute chapters to a series of other edited volumes (Duffin 2017a, in press b).

(11) Professional recognition – following proposal by Professor Peregrine Horden, my body of historical work was accepted as meeting the criteria for admission to the Royal Historical Society as FRHistS.

(12) Editorial work – I have recently been appointed to the Editorial Board of *The Pharmaceutical Historian* by the British Society for the History of Pharmacy, for whom I also serve as Programme Secretary.

(13) Referee – I have been asked to act as a referee for history of medicine papers in a variety of journals including

a. Geological Society of London Special Publications
b. Pharmaceutical Historian
c. Vesalius
d. Acta medico-historica Adriatica
e. Medicina Historica
f. Acta Historiae Medicinae

4. Research methodology

My pursuit of this research topic began somewhat casually as points of interest were stimulated, often by throwaway remarks or folklore anecdotes in both semi-popular literature and serious academic publications. Attempts to discover more substantial research in this topic area were met with a dearth of information, so I set about trying to answer the question 'What is the extent of pre-scientific folklore pertaining to geological materials?'. It quickly became obvious that much folklore information, belonging to oral tradition, was relatively inaccessible and relied upon written records and compilations, mostly by Victorian polymaths. Much medical folklore, on the other hand, had clearly become incorporated into mainstream academic texts from classical times onwards, and provided a rich potential, untapped source of information. My overall approach has consequently largely been as follows :

(a) Identification and selection of a suitable mineral material for investigation, usually either on the basis of written records or as an item of historical material culture, usually from *materia medica* collections.

(b) Collection of as much data as possible concerning contemporary uses of the material by using the usual online digital resources, plus specialist libraries, manuscript sources, archives and museum and other collections.

(c) Secondary literature has provided some useful references which I might otherwise have missed. Wherever possible, I have read the primary literature in the original language, seeking specialist assistance for the clarification of key sections of text when necessary. Some primary literature is available in translation.

(d) Systematic analysis of the gathered information, such as classifying the treatments for which the mineral materials were used by disease group or means of administration, allowing the identification of any particular trends inherent in the records, making comparisons with other materials, and assessing the stability of usage of the mineral material as a medicament.

(e) Consideration and contextualisation of the results of the initial analysis against the backdrop of the general history of medicine and the various social factors that have influenced its development. Assessment of any outliers in the data set; these might be due to historical factors, or be the result of conflation of information etc.

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Appendix 1. Further publications relevant to this body of work

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Table 1. Table to show mineral materials considered in papers by C. Duffin

Group	Subgroup	Name	Identity	Reference	Amulet	Galenical	Iatrochemical
ABIOGENIC	Rocks	*Lapis hibernicus*	Slate	Duffin 2013h		X	
		Lapis nephriticus - 'Nephritic Stone'	Nephrite jade	Duffin 2006 : 57	X		
				Duffin 2013h : 226-227	X		
		Spuma maris	Pumice	Duffin 2013g : 157-169		X	
		Stone powder	Stone powder	Weertz, Weertz & Duffin 2014: 27-32		X	
		Lapis lazuli	Lapis lazuli	Duffin 2014 : 84-87	X	X	
		Alectorius	possible gastrolith	Duffin 2007 : 325-341	X		
				Duffin 2012a : 182	X		
				Carrasco & Duffin 2017		X	
		Quirin	Hoopoe Stone	Duffin 2012a : 182-184	X		
		Chloritis	Wagtail Stone	Duffin 2012a : 184	X		
		Corvina	Crow Stone'	Duffin 2012a : 185-186	X		
		Calculi Pinguinum	Penguin Stone	Duffin 2012a : 186	X		
		Ostrich Stone	Ostrich Stone	Duffin 2012a : 186	?		
		lapide palumbellarum	Pigeon Stone	Duffin 2012a : 186-187		X	
		Vulturis	Vulture Stone	Duffin 2012a : 187-189	X		
	Minerals	*Aetites*	Eagle Stone - siderite nodule	Duffin 2012a : 189-191	X		
				Duffin 2013h : 222	X		
		Chelidonius	Agate	Duffin 2013c : 81-95		?	
		Saphiri	Sapphire	Duffin 2013f : 87-91		X	
		Sard	Chalcedony	Duffin 2013f : 91		X	
		Granat	Garnet	Duffin 2013f : 91		X	
				Duffin 2013h : 226		X	
		Emerald	Emerald	Duffin 2013f : 91		X	
		Rubini	Ruby	Duffin 2013f : 91		X	
		Haematite	Haematite	Duffin 2013h : 222-223		X	
		Selenite	Selenite	Duffin 2013h : 225-225		X	
		Pyrite	Pyrite	Duffin 2013h : 226		X	
		Crystallus	Rock crystal - Quartz	Duffin 2013h : 226		X	
		Cinnabar	Cinnabar	Duffin 2013h : 227		X	X
		Callaina	Turquoise?	Duffin 2012a : 184-185	X		
	Earths	*Terra sigillata*	Healing earth	Duffin 2013h : 224-225		X	
MINERALOIDS	Organic	*Succinum*	Amber	Duffin 2008 : 44-67	X	X	X
				Duffin 2013d : 46-53	X	X	
				Duffin 2013h : 221-222		X	
				Duffin 2015b : 41-74		X	
				Duffin in press a	X	X	X
		Gagates	Jet	Duffin 2013h : 223-224	X	X	X
	Inorganic	*Silex*	Flint	Duffin 2009 : 61	X		
				Duffin 2010d : 60	X		
				Duffin 2011a : 86-95	X		
BIOGENIC	Extant	Unicorn horn	Narwhal tusk	Duffin 2015 : 6-7	X		
		Cinaedia	Fish otoliths	Duffin 2007a : 78-90	X		
				Duffin 2016 : 6-7	X		
		Zahir mora	Adjutant Stork Stone	Duffin 2012b : 180-181		X	
		Bezoar	Bezoar	Duffin 2010b : 23		X	
				Duffin 2013a : 3-4	X		
				Duffin 2013b : 13-22	X	X	
	Fossil	*Lapis judaicus : 'Jews' Stones'*	Fossil echinoid spines	Duffin 2006a : 265-275		X	
				Duffin 2006b : 57-58		X	
				Duffin 2008 : 29-34		X	
				Duffin 2013h : 219		X	
		Lapis lincis : 'Lynx Stones	Fossil belemnites	Duffin 2006b : 58-59		X	
				Duffin 2008 : 11-29		X	
				Duffin 2013h : 220-221		X	
		Lapis bufonius : 'Toad Stones'	Fossil fish teeth	Duffin 2008 : 34-44	X		
				Duffin 2010a : 3-4	X		
		Glossopetrae - 'Tonguestones'	Fossil sharks' teeth	Duffin 2011b : 3-4	X		
				Duffin 2012a : 4-5	X		
				Duffin in press (a)	X		
				Duffin (in press) b	X		
		Porosphaera	Fossil sponge	Duffin 2009 : 62	X		
				Duffin 2011a : 95-97	X		
		Chelidonius	Fossil orbitoline foraminiferan	Duffin 2013c : 81-95	X	X	
		Chelidonius	Fossil fish tooth	Duffin 2013c : 81-95	X		
		Shih-yen	Fossil brachiopod	Duffin 2013c : 95-97		X	
		Cannel Coal	Sporinite	Duffin 2013h : 223-224		X	
ARTIFICIAL		*Lapis de Goa*	Goa Stone	Duffin 2010b : 22-32		X	
				Duffin 2010c : 42-46		X	
				Duffin 2013c : 219-220		X	
				Duffin & Pymm 2015a : 2		X	
		Lapis moraccolocius	Moraccolocius Stone	Duffin & Pymm 2015a : 2-3			X
		Lapis safonya	Safonya Stone	Duffin & Pymm 2015a : 3			X
		Amothist Stone	Amothist Stone	Duffin & Pymm 2015a : 3			X
		Lapis safaris	Safaris Stone	Duffin & Pymm 2015a : 3-4			X
		Lapis contrayerva	Contrayerva Stone	Duffin & Pymm 2015a : 4-5			X
		Lapis Alexiterius	Alexiterial Stone	Duffin & Pymm 2015a : 5			X
		Treacle Stone	Treacle Stone	Duffin & Pymm 2015a : 6			X
		Lapis mirabilis	Wonderful Stone	Duffin & Pymm 2015a : 6-7			X
		Lapis medicamentosus	Medical Stone	Duffin & Pymm 2015b : 28-29			X
		Lapis salutis	Stone of Health	Duffin & Pymm 2015b : 29			X
		Geoffroy's Stone	Geoffroy's Stone	Duffin & Pymm 2015b : 29-30			X
		Lapis divinus	Divine Stone	Duffin & Pymm 2015b : 30			X
		Lapis infernalis	Infernal Stone	Duffin & Pymm 2015b : 30-31			X
		Lapis seu sal Prunellae	*Lapis seu sal Prunellae*	Duffin & Pymm 2015b : 31			X
		Lapis attrahens venenum	Poison-attracting stone	Duffin & Pymm2015b : 31			X

Table 2. Table to show referencing data for History of Medicine publications by C. Duffin

Data as at 11th August 2017					
Date	**Short title**	**Google citations**	**Researchgate traffic**	**Researchgate citations**	**Academia.edu traffic**
in press	Magico-medicinal objects				
2017	Amber				
2017	Men methods materials		6		
2017	Unicorn horn		5		
2017	Alectorius	1	10		
2017a	Fossil sharks' teeth		13		
2016c	Jewel in Fish's Head		69		66
2015	Lapidary of Sidrac		98		42
2015	Internal use of amber	4	87		26
2015	Artificial Stones 2		72		45
2015	Artificial Stones 1		88		88
2015	The Danny Jewel		51		66
2014	Lapis lazuli		45		264
2014	Therapeutic stone powder		223		51
2013	Materia medica	2	28	2	9
2013	Pumice	2	22		4
2013	Gem electury	9	17		7
2013	Research sources	4	21		9
2013	External use of amber	1	239		92
2013	Chelidonius	4	368	2	32
2013	Porcupine stones	5	4253		386
2013	Bezoars and their mounts	6	243	2	503
2012	Petrus Hispanus	2	55	1	404
2012	Birds and fabulous stones	9	293	3	25
2012	Natternzungenkredenz	4	110	6	279
2011	Petrus Christus		58	1	100
2011	Witchstones	5	131	3	22
2010	Night-mare	3	67	2	23
2010	Lapis de Goa 2	5	173	8	7
2010	Lapis de Goa 1	12	136	12	42
2010	Toad Stone		47	2	1236
2009	Herbert Toms		121	3	19
2008	Fossils as drugs		275	13	143
2007	Alectorius	10	287	6	222
2007	Fish otoliths	11	92	8	263
2006	Stones for the stone	9	37	7	24
2006	Lapis judaicus	13	617	12	22
2005	Western Lapidary tradition	16	47	8	34
	Totals	**137**	**8504**	**101**	**4555**

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