Among our positive acquisitions from Arab law, there are legal institutions such as limited partnership (qirād), and certain technicalities of commercial law. But even omitting these, there is no doubt that the high ethical standard of certain parts of Arab law acted favourably on the development of our modern concepts; and herein lies its enduring merit.

D. de Santillana.

SCIENCE AND MEDICINE

§ 1. Early Period to A.D. 750
§ 2. Age of Translation from about 750 to about 900
§ 3. The Golden Age from about 900 to about 1100
§ 4. Age of Decline from about 1100
§ 5. The Legacy

The treasure-houses of Islamic science are just beginning to be opened. In Constantinople alone there are more than eighty mosque libraries containing tens of thousands of manuscripts. In Cairo, Damascus, Mosul, and Baghdad, as well as in Persia and India, there are other collections. Few have been listed, much less described or edited. Even the catalogue of the Escorial Library in Spain, which contains a large part of the wisdom of western Islam, is not yet complete. During the last few years the mass of material recovered has gone far to subvert our former conceptions and has thrown a flood of new light on the early history of scientific thought in the Islamic world. Thus at present even an outline of the medical and scientific achievement of Islam can, at best, be but tentative.

§ 1. Early Period to A.D. 750

When, in the seventh century, the Arabs first entered into the heritage of an ancient civilization, they brought with them apart from their religious and social ideals, no spiritual contribution save their music and their language. The rich and flexible tongue of Arabia was destined to become the scientific idiom of the Near East, just as Latin grew into a medium of scientific understanding in the West.

The Arabian pre-Islamic and early Islamic poetry shows that the Bedouins possessed a certain knowledge of the animals, plants, and stones of their vast peninsula. Their poets had a predilection for describing the qualities of their riding-camels and horses, and
gradually replaced Greek in the learned circles of western Asia. The bearers of this Syro-Hellenistic civilization were mainly the Nestorians. This Christian sect was founded in A.D. 428 by Nestorius, patriarch of Constantinople. Its adherents were condemned as heretical by the Council of Ephesus in 431 and thereupon migrated to Edessa. Expelled thence in 489 by the Byzantine Emperor Zeno, they emigrated to Persia, then under Sassanian rule, where they were well received. Pushing yet farther eastward, with missionary zeal, they penetrated the heart of Asia and reached even as far as western China.

The Nestorian scientific centre, which included a medical school, was transferred from Edessa to Nisibis in Mesopotamia, and again in the first half of the sixth century to Judeshapür in south-west Persia. There, besides a large hospital, an academy had been founded in the fourth century by the Sassanian monarch. The great king Chosroes Nāshirwān (531–79) made the city the most important intellectual centre of the time. Here Greek scholars who had left Athens when Justinian closed the philosophical schools in 529 came to meet Syrian, Persian, and Indian sages. Thus arose a scientific syncretism which later became important for the development of Islamic thought. Chosroes sent his own physician to India in search of medical books. These were then turned from Sanskrit into Pahlavi (Middle Persian), and many other scientific works were translated from Greek into Persian or Syriac. A disciple of the medical school of Judeshapür and a contemporary of the Prophet was the first scientifically trained medical man in Arabia, and is cited by the Quranic traditionists.

The first important scientific figure in the Syriac-speaking world was Sergius of Rēsh-'Ainā (d. 536) who was not a Nestorian but a Monophysite (Jacobite) Christian priest and chief physician in his Mesopotamian birth-place. It was he who began the task of translating the Greek medical literature into Syriac. Versions of many important works of Galen are ascribed
to him. Though crude, they were sufficient to maintain Greek medical tradition in western Asia for more than two centuries. During this period scholars began to write medical treatises of their own, based on Greek medicine. The best known of these were the Pandects of Ahrón, a Christian priest and physician in Alexandria shortly before the rise of Islam. The work was perhaps originally composed in Greek, but soon translated into Syriac and later into Arabic. The writing of Ahrón has not survived, but it seems to have contained the first description of small-pox, a disease unknown to ancient Greek medicine.

References to works on the natural sciences, from the centuries immediately preceding the rise of Islam, are rarer than those of a medical character. At some early period the Parva naturalia of Aristotle and certain pseudo-Aristotelian books On the cosmos and On the soul, appeared in Syriac, as did also the Physiologus, a Christian theological treatise on animals and their legendary powers and qualities. In the same language appeared versions of Greek treatises on cattle-breeding, agriculture, and veterinary medicine, as well as alchemical tracts. Some early Syriac fragments on metallurgical technical procedure still survive. It is probable that during the Sasanian rule the main centres of alchemical and astrological study were the great towns in the eastern and northern provinces of Persia, where Chinese and Indian influences were being welded to form a new civilization.

When the Arabs overran north Africa and western Asia they left the Byzantine and Persian administrative and scientific institutions almost untouched. The academy of Jundishapur continued as the scientific centre of the new Islamic empire. From here, during the Umayyad period (661–749), learned men, especially physicians, came to Damascus, the capital. They were mostly Christians or Jews bearing Arabic names. It was a Persian Jew, Māsarjawašt, who translated Ahrón’s Pandects into Arabic, and was responsible for what was probably the earliest scientific book in that language. History however is almost silent concerning scientific aims at the court of the Umayyad Caliphs.

§ 2. Age of Translations from about 750 to about 900.

The rise of the Abbasids about 750 inaugurated the epoch of greatest power, splendour, and prosperity of Islamic rule. At the very dawn stands the figure of a Muslim whose shadow lies athwart the science of the Middle Ages in the Orient as in the Occident. Jābir ibn Ḥāyān called al-Ṣūfī (that is ‘the Mystic’), the Geber of medieval Latin literature, was the son of an Arabic druggist in Kufa who died a martyr of the Shi‘ite propaganda. Jābir practised as a physician, but no record of his medical writings has come down to us, though the author of this essay has recently been able to recover a work ascribed to him on poisons. Jābir is famous as the father of Arabic alchemy. As we write there arrives evidence, however, that the works ascribed to him are of the tenth century, where we shall accordingly consider them (p. 325).

Jābir is said to have been closely attached to the family of the Barmaedis, the powerful viziers of Hārūn ar-Rashīd. He was implicated in their downfall in A.D. 803 and died in exile at Kufa, his father’s birthplace, where it is said that his laboratory was found in ruins two hundred years later.

In the time of the second Abbasid Caliph al-Manṣūr (754–75) the task of translation of Greek wisdom was taken up again, notably at Jundishapur. From there the ruler, when sick, sent for Jūrjūs (George) of the Christian family of the Bukht-Yishū’i (‘Jesus hath delivered’), chief physician at the renowned hospital. Another member of the same family was later consulted by the Caliphs al-Hādi (d. 786) and Hārūn ar-Rashīd (d. 809). The Bukht-Yishū’i family produced no less than seven generations of distinguished physicians, the last of whom lived into the second half of the eleventh century A.D. It was doubtless the skill of the first Bukht-Yishū’i that made the caliphs desire to
propagate Greek medical knowledge among the physicians of their empire.

The ninth century was the period of greatest activity in the work of translation. The old Syriac versions of Sergius were revised and new ones added. The translators, mostly Nestorian Christians, had a command of the Greek, Syriac, and Arabic languages and often also of Persian. Most of them wrote first in Syriac. The venerable Yūḥannā ibn Māsawayh (d. 837), however, who was for half a century physician to Ḥārūn ar-Rashid’s successors, produced a number of medical works in Arabic. In general the Syriac versions were prepared for Christian disciples and friends, while those in Arabic were intended for Muslim patrons who were themselves sometimes men of learning.

During the reign of the Caliph Al-Ma’mūn (813–33) the new learning reached its first climax. The monarch created in Baghdad a regular school for translation. It was equipped with a library. One of the translators there was Ḥūnayn ibn Ishāq (809–77), a particularly gifted philosopher and physician of wide erudition, the dominating figure of this century of translators. We know from his own recently published Missive that he translated practically the whole immense corpus of Galenic writings. This amounted to a hundred Syriac, and thirty-nine Arabic versions of Galen’s medical and philosophical books. His disciples, of whom his son Ishāq and his nephew Ḥubaysh were the most prominent, produced some thirteen Syriac and sixty Arabic translations. Thus was transmitted to the Islamic world the whole legacy of the most voluminous of the Greek scientific writers.

Ḥūnayn’s predilection for the scholastic turn in Galen’s theories is everywhere apparent. It was Ḥūnayn who gave Galen his supreme position in the Middle Ages in the Orient, and indirectly also in the Occident. Concerning the works of Hippocrates we are less well informed. Hunayn himself translated his Ἀφόρισμα, and this version remained classical for the later Arabs who frequently commented on it. Most of the other Hippocratic works were translated by Hunayn’s disciples. These versions were often revised by the master, who himself rendered into Syriac and Arabic nearly all the commentaries that Galen had himself written upon Hippocrates. Hunayn translated moreover the great Synopsis of Oribasius (325–403), the Seven Books of Paul of Aegina—both voluminous works—and the important and exceedingly influential Materia Medica of Dioscorides (fl. c. 60) which had been badly rendered by a former translator. This work was yet again translated into Arabic in Spain during the second half of the tenth century (see p. 330). Magnificent illustrated Arabic manuscripts of these Arabic translations of Dioscorides are contained in various libraries. Among the Arabic translations ascribed to Ḥūnayn are works of other Greek physicians and veterinary writers, together with several Aristotelian physical works and the Greek Old Testament (the Septuagint). Many of Ḥūnayn’s translations are still extant in manuscript, particularly in the libraries of Constantinople. They exhibit a free and sure mastery of the language, an easy adaptation to the Greek original, and a striking exactness of expression without verbosity. The superiority of Ḥūnayn’s workmanship was so generally recognized that many of the minor translators ascribed their productions to the great master.

Ḥūnayn’s own compositions are nearly as numerous as his translations. They include many summaries of, and commentaries on, Galen’s works, and skilful extracts and recapitulations in the form of text-books for students. Among the Arabs and Persians the most renowned of his books were the Questions on Medicine, a manual in the form of query and answer, and Ten Treatises on the Eye, which is the earliest systematic text-book of ophthalmology known. Several important works of Galen, though lost in their Greek original, have been preserved for us in the Arabic translations made by Ḥūnayn or his pupils.
Hunayn ibn Ishāq had several contemporaries who are considered ‘great’ translators, besides some ninety pupils who undertook similar work of less importance. In the former class were his nephew Ḥabaysih, his son Ishāq (d. 910), the great physician and mathematician, Thābit ibn Qurra (825–901) of Harrān in Mesopotamia, and Qustā ibn Lūcā (Constantine, son of Luke, fl. c. 900). All these except Thābit were Christians, like the majority of the physicians of the ninth century. Thābit himself was a heathen ‘Ṣabīʾan’ or star-worshipper. Hunayn and Ḥabaysih translated medical writings almost exclusively, their colleagues devoted themselves rather to astronomical, physical, mathematical, and philosophical Greek works. All of them produced also works of their own composition, the titles of which run into many hundreds. In the first half of the ninth century scientific works in the Syriac language predominated, but as the century wore on Arabic works became more numerous. Accompanying this process was the disappearance of the old school of Junḍahlūr, all its famous physicians and scientists having been gradually transferred to Baghdād and Sāmarrāʾ, the brilliant residences of the caliphs.

About 856, al-Mu’tawakkil re-founded at Baghdād the library and translation school, the direction of which was entrusted to Hunayn. The caliphs and their grandees furnished the necessary means to allow the Christian scholars to travel in search of Greek manuscripts and to bring them to Baghdād for translation. Thus Hunayn himself relates concerning a work of Galen now lost, and rare even at that date, ‘I sought it earnestly and travelled in search thereof in Mesopotamia, Syria, Palestine, and Egypt, until I reached Alexandria. Yet I was not able to find aught save about half of it at Damascus.’ He says that he always tried to work from at least three manuscripts of a Greek book so as to collate them and restore their text properly—a very modern conception of the duty of an editor.

As for medical learning in Baghdād, an interesting passage in Hunayn’s recently published *Missive on the Galenic Translations* shows us the Greek traditions fully alive there in 856. Thus he gives a picture of how the *Twenty Books* of Galen were being studied. ‘The reading of the students of the Medical School at Alexandria was confined to these books, keeping to the order which I have followed in my list. They were accustomed to meet daily to read and interpret one of the standard works, as in our days our Christian friends meet daily at the educational institutions known as *schola* (askūl) to discuss a standard work from among the books of the Ancients. The remainder of Galen’s books they used to read each for himself, after an introductory study of the afore-mentioned books, just as our friends to-day do with the explanations of the books of the Ancients.’ At this period, as well as later, full liberty to teach was granted in the schools and mosques of Baghdād.

Besides the translations of Greek works and their extracts, the translators made manuals of which one form, that of the ‘pandects’, is typical of the period of Arabic learning. These are recapitulations of the whole of medicine, discussing the affections of the body, systematically beginning at the head and working down to the feet. Most of these pandects are lost. One however was republished at Cairo only a few months ago. It was ascribed to Thābit ibn Qurra (p. 318), more celebrated as a translator and astronomer than as a physician. It is divided into thirty-one sections. The subjects treated are hygiene, ‘hidden’ and general diseases, e.g. those of the skin; then comes a section occupying the bulk of the work—on diseases of parts from the head, down through the breast, stomach, and intestines to the extremities; then follows a discussion on infectious diseases, among which are small-pox and measles; and here also poisons find a place; next is an account of climate, then of fractures and dislocations, then of food-stuffs and diet, and lastly of matters of sex. The exposition of each disease, its causes, symptoms, and
treatment, is given in clear and succinct language. Many Greek and Syriac authors are quoted.

Another kind of medical literature, much in favour with the Arab scholars, was the cram book in the form of questions and answers. Such books have survived in hundreds of manuscripts and have done much to give to Arabic medicine its scholastic aspect.

As regards the process of translation of the Greek works on the sciences other than medicine, our sources of information are somewhat meagre. Most of the Aristotelian scientific corpus was rendered into Syriac and Arabic by unknown translators. The *Physics*, the *Meteorology*, the *De Anima, De Sensu, De Coelo, De Generatione et Corruptione*, the *Historia Animalium*, together with works on botany, mineralogy, and mechanics spuriously ascribed to the great philosopher, all became accessible in these languages. Some treatises of neo-Platonic origin such as the *Secret of Creation* and the famous *De Causis*, ascribed to Apollonius of Tyana (called Bālinās by the Arabs), and other apocryphal works of Hellenistic scientists appeared in Arabic dress. Many Greek alchemical works, all or most under false ascriptions, were also translated. During the ninth century AD, however, no progress in chemistry is recorded, and two of the great scientists, Hunayn and al-Kindī (d. c. 873), were violent opponents of alchemical practices which they considered fraudulent.

We turn now from the translations to the original works of the period. In physics al-Kindī is the most frequently named scholar. No less than 265 works are ascribed to this first Muhammadan 'Philosopher of the Arabs'. Of these at least fifteen are on meteorology, several are on specific weight, on tides, optics and notably on the reflection of light, and eight are on music. Unhappily the bulk of al-Kindī's scientific output is lost. His *Optics*, preserved in a Latin translation, influenced Roger Bacon and other western men of science.

The technical arts were rapidly developing in Mesopotamia and Egypt, where irrigation works and canals for water-supply and communications were created. Theoretical mechanics roused much interest, and many books on elevation of water, water-wheels, on balances and on water-clocks were written. The earliest treatise on mechanics extant appeared about 860 as the *Book of Artifices* by the mathematicians Muhammad, Ahmad, and Ḥasan, sons of Mūsā ibn Shākir, who were themselves patrons of translators. This book contains one hundred technical constructions of which some twenty are of practical value, among them being accounts of vessels for warm and cold water, and water wells with a fixed level. Most are descriptions of scientific toys such as drinking-vessels with musical automata and the like, based on the mechanical principles of Hero of Alexandria.

In natural history a special type of literature arose during the eighth century. It took the form of accounts of animals, plants, and stones composed with a literary aim, but containing useful information. One of the most prominent authors of such works was the famous Arabic philologist al-ʾAmai of Bayra (A.D. 740–828). He composed books *On the Horse, On the Camel, On Wild Animals, On Plants and Trees, On the Vine and the Palm-Tree, On the Making of Man*, and several other writers produced comparable works. A book that has caused much controversy is the *Nabataean Agriculture* of Ibn Wafṣhīyya (c. A.D. 800). It contains some useful information on animals, plants, and their cultivation, mingled with legends and forged translations from Babylonian and other Semitic sources. The Syriac version of the work on husbandry (*Geoponica*) by the Byzantine scholar Cassianus Basus (c. 550) was translated into Arabic by different scholars.

After the Arabic edition of Aristotle's apocryphal *Mineraology* many Islamic writers composed books on stones, particularly precious stones, which form a special *genre*, the 'lapidary', after-
wards both translated and imitated in the West. Nearly all those we have mentioned, from 'Jābir' to al-Kindi, were authors of such pamphlets. Al-Kindi moreover wrote several small works on iron and steel for weapons. The increasingly close connexion between the caliphs' empire and eastern and southern lands, e.g., Turkistan, India, and the east African coasts, increased the influx of rare and precious stones and the knowledge of them. Thus some modern names of stones still bear traces of Arabic or Persian contacts, for example the bezoar (Persian: pād-zahr, i.e. protecting against poison). So too many plants, drugs, and species unknown to the Greeks came through the Persians, e.g. camphor (an Arabic word of Persian origin) and galanga-root (Persian khūlinjān from Chinese kowliang-chang) from the Sunda Islands, musk from Tibet, sugar-cane from India, amber from the coasts of the Indian Ocean. Pharmacological and toxicological treatises were composed by many of the Arabic-writing physicians from Jābir ibn Ḥayyān onwards. Paper was introduced from China into the Islamic world in the eighth century and in A.D. 794 the first Islamic paper-manufacture was established in Baghdād.

§ 3. The Golden Age from about 900 to about 1100.

At the end of the period of translation, the physicians and scientists of the Islamic world stood on a firm foundation of Greek science, increased by a large share of Persian and Indian thought and experience. Their work had been learned but not very original. From this time on they begin to rely upon their own resources and to develop from within.

The sciences, particularly medicine, now pass rapidly from the hands of Christians and Šābians into the possession of Muslim scholars, mostly Persians. In medicine, in place of pandects compiled from antique sources, we find imposing encyclopaedic works in which the knowledge of former generations is carefully classified and set against that of the moderns.

The first and surely the greatest of the writers of this new school is al-Rāzī, the author known to the Latin West as Rhazes (c. 865–925), a Persian Muslim born at Rayy near modern Tehrān. Rhazes was undoubtedly the greatest physician of the Islamic world and one of the great physicians of all time. He studied in Baghdād under a disciple of Hunayn ibn Ishāq, who was acquainted with Greek, Persian, and Indian medicine. In his youth Rhazes practised as an alchemist, but in his later years, when his reputation attracted pupils and patients from all parts of western Asia, he devoted himself exclusively to medicine. His erudition was all-embracing, and his scientific output remarkable, amounting to more than 200 works, half of which are medical.

The writings of Rhazes on medicine included many short missives of an ephemeral character. Their very titles bring a human element into what must be, for most readers, a somewhat arid theme. On the fact that even skilful physicians cannot heal all diseases: why frightened patients easily forsake even the skilful physician; why people prefer quacks and charlatans to skilful physicians; why ignorant physicians, laymen, and women have more success than learned medical men, are among his lighter topics. Other of his missives treat of separate diseases, for example of stone in the bladder and in the kidneys, both very common conditions in the near East. We have also by him treatises on anatomy. The most celebrated of all the works of Rhazes is that On Small-pox and Measles. It was early translated into Latin and later into various languages, including English, being printed some forty times between 1498 and 1866. It gives the first clear account of these two diseases that has come down to us. An extract will convey to the reader something of the observing spirit of the original.

"The outbreak of small-pox is preceded by continuous fever, acheing in the back, itching in the nose and shivering during sleep. The main symptoms of its presence are: back-ache with fever, stinging pain in the whole body, congestion of the face, sometimes shrinkage, violent
redness of the cheeks and eyes, a sense of pressure in the body, creeping of the flesh, pain in the throat and breast accompanied by difficulty of respiration and coughing, dryness of the mouth, thick salivation, hoarseness of the voice, headache and pressure in the head, excitement, anxiety, nausea and unrest. Excitement, nausea and unrest are more pronounced in measles than in small-pox, whilst the aching in the back is more severe in small-pox than in measles.

Rhazes gives sound and detailed advice as to the treatment of the pustules after the full development of small-pox. These pustules are of course the cause of the unsightly scars left by the disease, which is still common in the East.

The greatest medical work of Rhazes, and perhaps the most extensive ever written by a medical man, is his al-Ḥāwī, i.e. ‘Comprehensive Book’, which includes indeed Greek, Syriac, and early Arabic medical knowledge in their entirety. Throughout his life Rhazes must have collected extracts from all the books on medicine which he had read, together with his whole medical experience. These he combined in his last years into this enormous manual. The Arabic biographies agree in saying that he could not finish his work and that after his death his disciples gave it its actual form. Of the more than twenty volumes of which the Ḥāwī consisted about ten only are in existence, scattered in eight or more public libraries. Half a century after Rhazes only two complete copies were known, but I have myself found a note in the book of an oculist of the Bukht-Yishā‘ family of about A.D. 1070 to the effect that he had hadd occasion to consult five copies of the Ḥāwī’s ophthalmic section. For each disease Rhazes first cites all the Greek, Syrian, Arabic, Persian, and Indian authors, and at the end gives his own opinion and experiences, and he preserves many striking examples of his clinical insight.

The Ḥāwī was translated into Latin under the auspices of Charles I of Anjou by the Sicilian Jewish physician Faraj ibn Sālim (Farragut) of Girgenti, who finished his enormous task in 1279. He rendered the name al-Ḥāwī by continens, and as the Liber Continens (see Legacy of Israel, p. 221) this greatest work of Rhazes was propagated in numerous manuscripts during the following centuries. It was repeatedly printed from 1486 onwards. By 1542 there had appeared five editions of this vast and costly work, besides many more of various parts of it. Its influence on European medicine was thus very considerable.

Besides medicine, Rhazes left writings on theology, philosophy, mathematics, astronomy, and the ‘natural sciences’. The last deal with matter, space, time, motion, nutrition, growth, putrefaction, meteorology, optics, and alchemy. The importance of Rhazes’ alchemical work has been brought to light during the last few years only. His great Book of the Art (of Alchemy) was recently discovered in the library of an Indian prince. Although dependent partly on the same sources as ‘Jābir’, Rhazes excels him in his exact classification of substances, and in his clear description of chemical processes and apparatus, which is always devoid of mystical elements. While ‘Jābir’ and the other Arabian alchemists divide mineral substances into ‘Bodies’ (gold, silver, &c.), ‘Souls’ (sulphur, arsenic, &c.), and ‘Spirits’ (mercury and sal-ammoniac), Rhazes classifies alchemical substances as vegetable, animal, or mineral, a conception which comes from him into modern speech. The class of minerals he divides into spirits, bodies, stones, vitriols, boraxes, and salts. He distinguished volatile ‘bodies’ and non-volatile ‘spirits’, placing among the latter sulphur, mercury, arsenic, and salmias.

A prominent contemporary of Rhazes was the writer known to the West as Isaac Judaeus (855–955). This Egyptian Jew became physician to the Fatimid rulers of Qairawān in Tunisia. His works were among the first to be translated into Latin, the task being accomplished by Constantine the African about 1080. They exercised much influence on Western medieval medicine, and were still being read in the seventeenth century. Robert
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Burton (1577–1640) quotes them freely in his Anatomy of Melancholy. The books of Isaac On Fevers, On the Elements, On simple Drugs and Ailments, and above all, his treatise On Urine dominated medicine for many centuries. Very remarkable is his little tract, extant in a Hebrew translation only, Guide for Physicians. It shows a high ethical conception of the medical profession. Some of the aphorisms in this work are worthy of record: ‘Should adversity befall a physician open not thy mouth to condemn, for each hath his hour.’ ‘Let thine own skill exalt thee and seek not honour in another’s shame.’ ‘Neglect not to visit and treat the poor, for there is no nobler work than this.’ ‘Comfort the sufferer by the promise of healing, even when thou art not confident, for thus thou mayest assist his natural powers.’ A practical piece of advice excellent when dealing with Oriental patients is: ‘Ask thy reward while the sickness is waxing or at its height, for being cured he will surely forget what thou didst for him.’

Isaac’s most distinguished disciple was Ibn al-Jazzār (d. 1009), a Muslim, whose chief work Provision for the Traveller was early translated into Latin as the Vistricon, Greek (Ephodia) and Hebrew. It was very popular with medieval physicians, because it gave a good record of internal diseases, but it was ascribed by its translator Constantine to himself and not to the real author (see p. 346). The alchemical writings to which the name of Jābir is attached have long been a puzzle to scholars. If this Jābir be the eighth-century mystic of that name, it is difficult to understand how he could have obtained any knowledge of the still inaccessible Greek alchemical literature. As already indicated, however (p. 315), evidence is now available that the works bearing the name of Jābir were produced early in the tenth century. It appears that they were the work of a secret society similar to the so-called ‘Brethren of Purity’. In the medical work of Jābir, only Greek authors are quoted, but the diction is independent of theirs and shows a distinct scholastic trend. Syrian and Indian names of drugs are rarely used, but Persian terms abound. Thus we may consider this remarkable book to be a mixture of Greek scientific research and Persian practical knowledge of medicines and poisons. Anyhow it is doubtless the last link in a long chain of scientific development during pre-Islamic and Islamic times.

‘Jābir’ is world-famed as the father of Arabic alchemy. This word, al-kimiyā, is usually said to be derived from the Egyptian kam-it or kem-it, ‘the black’, or, as some have thought, from the Greek chyma, ‘molten metal’. The fundamental premises of this ‘science’ as established by Egyptian and Greek scholars were (a) that all metals are in reality the same, and that consequently a transmutation of one into another is possible; (b) that gold is the ‘purest’ of all metals, and silver next to it, and (c) that there is a substance capable of continuously transforming base into pure metals. These conceptions had the merit of provoking experiment, but were unfortunately accompanied by an inordinate tendency to theorize. Moreover, at Alexandria, the centre of Greek learning, and indeed throughout the Islamic realm, certain mystical tendencies derived from the Gnostics and the neo-Platonists had a very detrimental effect upon the experimental spirit. Alchemy, which in the hands of Jābir was a matter for experimental research, tended to become the subject of ineffable speculation and superstitious practice, passing into fraudulent deception.

About a hundred alchemical works ascribed to Jābir are extant. Many are little but confused jumbles of puerile superstition. But there are others which prove that the author recognized more clearly, and stated more definitely, the importance of experiment than any other early chemist. Thus he was enabled to make noteworthy advances in both the theory and practice of the subject. His influence can be traced throughout the whole historic course of European alchemy and chemistry.
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On the practical side, 'Jābir' described improved methods for evaporation, filtration, sublimation, melting, distillation, and crystallization. He described the preparation of many chemical substances, e.g. cinnabar (sulphide of mercury), arsenious oxide, and others. He knew how to obtain nearly pure vitriols, alums, alkalis, sal-ammoniac, and saltpetre, how to produce so-called 'liver' and 'milk' of sulphur by heating sulphur with alkali, and so on. He prepared fairly pure mercury oxide and sublimate, as well as acetates of lead and other metals, sometimes crystallized. He understood the preparation of crude sulphuric and nitric acids as well as a mixture of them, aqua regia, and the solubility of gold and silver in this acid.

Several technical terms have passed from 'Jābir's' Arabic writings through Latin into the European languages. Among these are realgar (red sulphide of arsenic), tussia (zinc oxide), alkali, antimony (Ar: ibhmid), alembic for the upper, and aludel for the lower part of a distillation vessel. A new chemical substance unknown to the Greeks which appears in 'Jābir's' works is sal-ammoniac. The ammoniacon of the Greeks was rock-salt, and it seems that the transference of the old name to a new salt was effected by the Syrians. A full appreciation of 'Jābir's' merits in chemistry will only be possible when the bulk of his chemical writings have been published, particularly his great Book of the Seventy. This composition of seventy discourses was till recently known only in an inferior and incomplete Latin version. The author of this article has had the good fortune to find the almost complete Arabic original.

The chemical writings to which 'Jābir's' name is attached were soon translated into Latin. The first such version, the Book of the Composition of Alchemy, was made by the Englishman Robert of Chester, in A.D. 1144. The translation of the Book of the Seventy into Latin was one of the achievements of the famous Gerard of Cremona (d. 1187, see p. 347). A work entitled the
Sun of Perfection is ascribed to 'Jābir' by the English translator Richard Russell (1678) who describes him as 'Geber, the Most Famous Arabian Prince and Philosopher'. Much evidence linking 'Geber' of the Latin writers with the Arabic alchemists has recently appeared from the pen of Dr. E. J. Holmyard.

In the Eastern caliphate there arose a generation of prominent physicians of whom we will first mention the Persian Muslim known to the Latins as Haly Abbas (d. 994). He composed an excellent and compact encyclopaedia, The Whole Medical Art, known also to the Latins as Liber regius (al-Kitāb al-Malikī). It deals with both the theory and practice of medicine. It begins with a most interesting chapter containing an explicit critique of previous Greek and Arabic medical treatises. This book was twice translated into Latin at an early date, but it was superseded by the Canon of the great Avicenna.

Abū 'Ali al-Husayn ibn Sinā, known universally to the West as Avicenna (980–1037), was one of the greatest scholars of the Islamic world, though less remarkable as a physician than as a philosopher and physicist. Nevertheless his influence on European medicine has been overwhelming. Ibn Sinā concentrated the legacy of Greek medical knowledge with the addition of the Arabs' contribution in his gigantic Canon of Medicine (al-Qānūn fi‘t-Ṭibb), which is the culmination and masterpiece of Arabic systematization. This medical encyclopaedia deals with general medicine, simple drugs, diseases affecting all parts of the body from the head to the feet, special pathology and pharmacopoeia.

The system of classification adopted in the Canon is most complex, and is in part responsible for the mania for subdivision which affected Western scholasticism. The book was translated into Latin by Gerard of Cremona in the twelfth century (p. 348) and his version exists in innumerable manuscripts. The demand for it may be gleaned from the fact that in the last thirty years of the fifteenth century it was issued sixteen times—fifteen editions being in Latin and one in Hebrew, and that it was
reissued more than twenty times during the sixteenth century. These figures do not include editions of parts of the work. Commentaries on it in Latin, Hebrew, and the vernaculars, both in manuscript and in print, are without number, and the book continued to be printed and read into the second half of the seventeenth century. Probably no medical work ever written has been so much studied, and it is still in current use in the Orient.

Some fifteen other medical works of Avicenna are known, together with about a hundred writings by him on theology, metaphysics, astronomy, and philology. Nearly all are written in Arabic except some poems which are in Persian, a language which acquired new importance during the tenth century. With Avicenna 'the Prince and Chief of Physicians' Islamic medicine reached its zenith in the East. To this day pious veneration surrounds the tomb of the great physician and philosopher at Hamadan in western Persia.

While the eastern Islamic world was gradually acquiring supremacy in medicine, western Islam developed also as a centre of this science. In Spain during the glorious reigns of the caliphs 'Abd al-Rahmān III and al-Ḥakam II of Córdoba, Hāshim ben Shaprūt (d. c. 990), a Jew, was at once minister, court-physician, and patron of science. In his younger years he translated into Arabic, with the help of the monk Nicholas, the splendid manuscript of the Materia Medica of Dioscurides which had been sent as a diplomatic present from the Byzantine emperor Constantine VII. Later Ibn Juljul, court-physician and medical historian, corrected this version and wrote a commentary on it.

The Muslim known to the Latins as Abulcasis (d. c. A.D. 1013) was likewise court-physician in Córdoba. His name is associated with a great Medical Vade mecum (at-Tafriḥ) in thirty sections, the last of which deals with surgery, an art which had till then been neglected by Islamic authors. The surgical treatise of
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Abulcasim is based largely on the sixth book of Paul of Aegina, but with numerous additions. His work contained illustrations of instruments which influenced other Arabic authors and especially helped to lay the foundations of surgery in Europe. It was early translated into Latin, Provençal, and Hebrew. The celebrated French surgeon Guy de Chauliac (1300–68) appended the Latin version to one of his works.

In Egypt, Syria, and Mesopotamia there was much medical activity in the eleventh century A.D. 'Ali ibn Riḍwān of Cairo (d.c. 1067) known to the Latins as Haly Rodoam, produced a fine medical topography of Egypt and was an ardent follower of Galen and the Greek authors. He declared that one could become a good physician solely by the study of the ancient works, which opinion gave rise to a long and violent polemic with his contemporary Ibn Būṭlān of Baghdād (d.c. 1063). Ibn Riḍwān’s commentary on Galen’s Ars parea, as well as Ibn Būṭlān’s Synoptic Tables of Medicine, a scholastic masterpiece, were translated into Latin.

Before leaving this period of Islamic medicine we have to consider some productions which are peculiar to it.

First come the treatises on simple drugs which form parts of the great encyclopaedias, but which were also composed as separate monographs by a series of other authors. Such treatises are still highly esteemed in the Orient. Abū Maṣṭūr Muwaffaq of Herāt in Persia wrote about 975 in Persian, The Foundations of the True Properties of Remedies describing 585 drugs. It contains besides Greek and Syriac, Arabic, Persian, and Indian knowledge. It is, moreover, the first monument of modern Persian prose. There were many treatises of the same type in Arabic. Among them we may mention those of Māsawayh al-Māridīnī of Baghdād and Cairo (d. 1015) and Ibn Wāfād in Spain (d.c. 1074). Both are well known in their Latin translations and were printed together some fifty or more times. In Latin they appeared as De Medicinis universalibus et particulari-
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bus by 'Mesue' the younger, and De Medicamentis simplicibus by 'Abenguefit'.

Ophthalmology was another branch of medicine which reached its height about A.D. 1000. The Christian oculist 'Ali ibn 'Isa of Baghdad known to the Latins as Jesu Haly, and the Muslim 'Ammar of Mosul, known as 'Canamusali', left two excellent treatises, increasing the Greek canon of ophthalmology with numerous additions, operations, and personal observations. Both were translated into Latin. They were the best text-books on eye-diseases until the first half of the eighteenth century when the Renaissance of ophthalmology set in in France.

In science we have mentioned the achievements of Rhazes and 'Jābir' in Alchemy. The two greatest spirits of the age, Avicenna and al-Bīrūnī, were firmly opposed to the subject. On the other hand we owe to Avicenna a treatise on the formation of mountains, stones, and minerals. It is important for the history of geology as discussing the influence of earthquake, wind, water, temperature, sedimentation, desiccation, and other causes of solidification.

Abu Rayḥān Muhammad al-Bīrūnī (973–1048) called 'the Master' ('al-Ustādī), a Persian physician, astronomer, mathematician, physicist, geographer, and historian, is perhaps the most prominent figure in the phalanx of those universally learned Muslim scholars who characterize the Golden Age of Islamic science. His Chronology of Ancient Nations and his Indian studies are known in good English translations. Most of his mathematical works and many other writings are waiting for publication. In physics his greatest achievement is the nearly exact determination of the specific weight of eighteen precious stones and metals. A voluminous unedited lapidary by al-Bīrūnī is extant in a unique manuscript in the Escorial Library. It contains a description of a great number of stones and metals from the natural, commercial, and medical point of view. He com-

posed, moreover, a pharmacology ('saydala'). Important information could certainly be obtained from his unedited works on the origin of Indian and Chinese stones and drugs which appear early in Arabic scientific works.

Al-Muṣṭafī (d. in Cairo c. 957) is in a restricted sense the 'Pliny of the Arabs'. In his Meadows of Gold he described an earthquake, the waters of the Dead Sea, and the first windmills, which are perhaps an invention of the Islamic peoples, and he also gives what has been described as the rudiments of a theory of evolution.

The 'Brethren of Purity' (Ikhwaṭn as-SAfsā), a secret philosophical society founded in Mesopotamia in the tenth century, wrote an encyclopedia composed of fifty-two treatises, seventeen of which deal with natural science, mainly on Greek lines. We find here discussions on the formation of minerals, on earthquakes, tides, meteorological phenomena, and the elements, all brought into relation with the celestial spheres and bodies. The work of the Brethren, although burnt as heretical by the orthodox clergy in Baghdad, spread as far as Spain where it influenced philosophic and scientific thought. Water-clocks were frequently constructed in the Islamic countries. One example was presented to Charlemagne by an embassy sent by Hārūn ar-Rashid.

The famous philosopher al-Fārābī, a Turkish Muslim (d. A.D. 951), must be mentioned here for his treatise On Music, the most important oriental work on the theory of music. He also wrote an important book on the classification of sciences. Two similar works of classification were composed some time after. One was the Keys of Sciences, written in 976 by Muhammad al-Khawārizmi. The other was the famous work Fihrist al-Ulam, i.e. Index of Sciences (988), by Ibn an-Nadim. The latter is of primary importance for our knowledge of early Islamic (and Greek) scientists and philosophers.

Optics was developed to its highest degree by Abū 'Ali al-
Hasan ibn al-Haytham (Alhazen) of Basra (965). He moved to Cairo where he entered the service of the Fatimid caliph al-Hakim (996–1020) and tried to discover a method of regulating the annual Nile inundation. Failing in this task he had to hide from the caliph’s wrath and simulate madness until al-Hakim’s death. He nevertheless found time not only to copy ancient treatises on mathematics and physics, but also himself to compose many works on these subjects and on medicine, his original profession. His main work is On Optics: the original Arabic is lost, but the book survives in Latin. Alhazen opposes the theory of Euclid and Ptolemy that the eye sends out visual rays to the object of vision. He discusses the propagation of light and colours, optic illusions and reflection, with experiments for testing the angles of incidence and reflection. His name is still associated with the so-called ‘Alhazen’s problem’: ‘In a spherical concave or convex, a cylindrical or conical mirror to find the point from which an object of given position will be reflected to an eye of given position.’ It leads to an equation of the fourth degree which Alhazen solved by the use of a hyperbola.

Alhazen examines also the refraction of light-rays through transparent mediums (air, water). In detailing his experiments with spherical segments (glass vessels filled with water), he comes very near to the theoretical discovery of magnifying lenses, which was made practically in Italy three centuries later, whilst more than six centuries were to pass before the law of sines was established by Snell and Descartes. Roger Bacon (thirteenth century) and all medieval Western writers on optics—notably the Pole Witelo or Vitello—base their optical works largely on Alhazen’s Opticae Theorarum. His work also influenced Leonardo da Vinci and Johann Kepler. The latter modestly entitled his fundamental work on dioptrics Ad Vitellionem Paralipomena (Frankfort 1604).

Commentaries on Alhazen’s Optics were written by Oriental authors, but most of his successors did not adopt his theory of vision; nor did the oculists of later periods of Islamic science. Al-Biruni however and Avicenna share independently and fully Alhazen’s opinion that ‘it is not a ray that leaves the eye and meets the object that gives rise to vision. Rather the form of the perceived object passes into the eye and is transmitted by its transparent body (i.e. the lens).’

Alhazen left several minor writings on physical optics, among them one On Light. He regards light as a kind of fire that is reflected at the spheric limit of the atmosphere. In On Twilight Phenomena, which is extant only in Latin, he calculates that this atmosphere is about ten English miles in height. Other of his treatises deal with the rainbow, the halo, and with spherical and parabolic mirrors. These and some other books on shadows and eclipses are of a highly mathematical character. On the basis of his calculations he constructed such mirrors of metal. Most of these works were products of the last ten years of Alhazen’s life, as was his fundamental study On the Burning glass, in which he created a dioptric far superior to that of the Greeks. The work exhibits a profound and accurate conception of the nature of focussing, magnifying, and inversion of the image, and of formation of rings and colours by experiments. Alhazen wrote moreover a commentary on the optical works of Euclid and Ptolemy, on the Physics of Aristotle, and on the Aristotelian Problemati. He observed the semi-lunar shape of the image of the sun during eclipses on a wall opposite a fine hole made in the window shutters—the first record of the camera obscura.

We may glance at the scientific institutions during this golden age of Islamic science. Hospitals were early founded, probably on the models of the old and celebrated academy-hospital of Jundishapur. From the Persian name for this is derived the title used for a hospital throughout the Islamic world (bimāristān). We have authentic information concerning at least thirty-four such institutions. They were distributed through the
We have already mentioned the 'House of Wisdom', created in Baghdad by the Caliph al-Ma'mun about A.D. 830. His nephew al-Mutawakkil followed his example, as did many grandees of his court. The caliph's friend and secretary 'Ali ibn Yahiya (d. 888) had a beautiful library in his country seat. In Cairo the Fātimid caliph al-Ḥakim founded in A.D. 995 a 'House of Science' the budget of which is known exactly. As orthodox theology became supreme it was suspended because of the danger of heresy.

The pilgrimage to Mecca and Medina, the duty of every Muslim, favoured the spread of science, since it compelled students from India and Spain, from Asia Minor and Africa, to pass through many lands where they could visit mosques and academies and have intercourse with prominent scholars. Moreover many came from Tunis to Persia, and from the Caspian Sea to Cairo and Córdoba, to follow the courses of famous teachers. The actual process of teaching was much as it is to-day. The professor sat with his back to a column, and round him gathered a ring of disciples. In the al-Azhar mosque of ancient fame in Cairo the tourist may usually see twenty or thirty such groups within the great hypostyle hall, giving what is in all probability a true picture of academic lessons as they were held in the days of ancient Greece and Córdoba.

§ 4. Age of Decline from about 1100

Whilst the orthodoxy of early Islam tolerated the sciences, we may say that, from the time of the famous religious teacher al-Ghazzālī (d. 1111) onwards, this tolerance gave place to persecution of these studies 'because they lead to loss of belief in the origin of the world and in the creator'. Whether or no this attitude was alone sufficient to prevent the rise of great independent thinkers, it was certainly a very important factor in their suppression. The twelfth century marks a standstill. The works
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of Rhazes, Avicenna, and ‘Jābir’ are reproduced, summarized, commented on, but outstanding and independent works are becoming rare.

Among the physicians an increasing number of Jews is to be observed, particularly at the courts of Baghdad and Cairo, and in Spain, perhaps because Jews were relatively free from the restraints of orthodox Islam. The prototype of the eminent Jewish court physician, practitioner, philosopher, and religious teacher, is Maimonides (1135–1204). Born in Spain, he spent most of his active life in Cairo under the great Saladin and his sons. His best medical work is his Aphorisms in which he even ventured to criticize the opinions of Galen himself. As a court official he wrote hygienic treatises for the sultan which are very typical specimens of medical literature during the later centuries of Islam. The influence of orthodoxy on the otherwise rather liberal court of Cairo is evident from the excuse given by Maimonides at the end of one of his tracts, in which he has a lengthy scientific apology for his advice to the sultan that he should indulge in the forbidden wine and music as a cure for his melancholy.

Maimonides’ younger contemporary, the Muslim ‘Abd al-Laṭif, travelled from Baghdad to Cairo to see renowned scholars and the land of Egypt, of which he then gave his famous description. After describing the famines and earthquakes in Egypt from A.D. 1200 to 1202 he gives an interesting account of his osteological studies in an ancient cemetery in the north-west of Cairo. He checked and corrected Galen’s description of the bone of the lower jaw and of the sacrum.

Pharmacological treatises abounded at this period. They were either on simple drugs, the most famous of which was that by Ibn al-Baytār (d. 1248), or on compound remedies. The latter treatises were called Agrābādīn (mutilation of Greek graphidion, i.e. small treatise). The word masquerades very frequently in Latin manuscripts and early printed books as

Grabadin. A Collection of Simple Drugs was composed by Ibn al-Baytār, who collected plants and drugs on the Mediterranean littoral, from Spain to Syria, described more than 1,400 medicinal drugs, and compared them with the records of more than 150 ancient or Arabian authors. It is a work of extraordinary erudition and observation, and is the greatest of the Arabic books on botany.

Later Arabic books on compound remedies are still in favour with the native druggists throughout the Islamic world. Among the most popular at the present day is the Management of the Drug Store by the Jew Kohēn al-‘Aṭār 14th century and the Memorial by Dāwūd al-Antākī (d. 1599), both composed in Cairo. Many of the old and complicated recipes of these books passed into the European dispensaries. Several names of remedies came thus to the West from the East. Among these we may note ṭārīb for a conserve of inspissated fruit-juice with honey, jūlep (Persian gālāb rose-water) for a medicinal aromatic drink, and sirāp (Arabic sharāb).

With the beginning of the fourteenth century magic and superstitious practices began to creep into the medical works of the Muslim writers, whose medical knowledge was often derived from religious writings. There is thus a further deterioration of the general standard of the material.

In Spain, the philosophical bias predominated among medical men. The prototypes of this combination are the two Muslims, Ibn Zuhūr (Avenzoar) and Ibn Rushd (Averroes). The former (d. in Seville 1162) was an aristocratic physician at the court of one of the Almohade rulers. He displayed disdain for surgery and surgeons and was more a consulting physician than a general practitioner. His chief work is the Facilitation of Treatments known by its Arabic name al-Tayyīrī, translated into Latin as Theisir in 1280 by Paracelsus, with the help of a Jew, in Venice, where it was later repeatedly printed. This book gives proof of remarkable independence of thought, being largely based on
personal experience. It is this, perhaps, which caused it to enjoy less success with the Arabs than in Europe. Averroes (d. in Morocco in 1198), disciple and friend of Avenceor, was among the very greatest of Aristotelian philosophers. He also wrote some sixteen medical works, one of which is well known in its Latin translation. This is the General Rules of Medicine (Kulliyat fi-Tibb) translated in 1255 by the Paduan Jew Bonacosa under the title of Colliget. It was several times printed, in conjunction with Avenceor's Theisir. Everywhere in his book Averroes reveals himself as an Aristotelian thinker, particularly in the second part where he deals with physiology and psychology. Often he pits the opinions of Razes and Avenceor against those of Hippocrates and Galen.

The great plague of the fourteenth century, the 'Black Death', furnished an occasion for Muslim physicians in Spain to free themselves from theological prejudice which regarded plague as a divine punishment and to consider the epidemic as a contagion. The celebrated Arab statesman, historian, and physician Ibn al-Khaṭīb of Granada (1313-74) described it in a famous treatise On Plague. In it we find, for example, the remarkable passage:

'The existence of contagion is established by experience, study, and the evidence of the senses, by trustworthy reports on transmission by garments, vessels, ear-rings; by the spread of it by persons from one house, by infection of a healthy sea-port by an arrival from an infected land . . . by the immunity of isolated individuals and . . . nomadic Beduin tribes of Africa . . . . It must be a principle that a proof taken from the Traditions has to undergo modification when in manifest contradiction with the evidence of the perception of the senses.'

This was a very bold statement in the days of darkest orthodoxy.

The Moorish physician Ibn Khārizma (d. 1369) wrote a book on the plague which ravaged Almeria in Spain in 1348-9. This treatise is far superior to all the numerous plague tracts edited in Europe between the fourteenth and the sixteenth centuries. He says:

'The result of my long experience is that if a person comes into contact with a patient, he is immediately attacked by the disease with the same symptoms. If the first patient expectorated blood, the second will do so. . . . If the first developed buboes, they will appear on the other in the same places. If the first had an oler, the second will get the same; and the second-patient likewise transmits the disease.'

To appreciate the teaching of these writers it must be remembered that the doctrine of the contagious character of disease is not emphasized by the Greek physicians and is almost passed over by most medieval medical writers.

In the sciences other than medicine the output of books during the period of decline was very great, but the deterioration was no less marked. Thus there are known books of some forty Arabic and Persian alchemists after the eleventh century. Yet their works add very little to the subject. It is noteworthy that Ibn Khaldūn (d. 1406) the talented Arabian philosopher of history, the greatest intellect of his century, was a violent opponent of alchemy.

Mineralogy stood in close relation to alchemy. Nearly fifty Arabic lapidaries have been named. The best known of them is the Flowers of Knowledge of Stones, by Shihāb al-Dīn al-Tīfāshī (d. in Cairo A.D. 1154). It gives in twenty-five chapters extensive information on the subject of the same number of precious stones, their origin, geography, examination, purity, price, application for medicinal and magical purposes, and so on. Except for Pliny and the spurious Aristotelian lapidary he quotes only Arabic authors.

The only important Muslim work on Zoology is the Life of Animals by Muhāammad ad-Damīrī (d. 1425 in Cairo). The author was a religious teacher, and therefore his book is not the result of personal experience but a compilation from all the available literary sources. Although a purely scholastic book it
achieved a great reputation in the Orient. In some parts it contains useful information on folklore, popular medicine and racial psychology, but always overgrown with a bewildering mass of incoherent narratives.

The many cosmographical encyclopaedias of the Arabs and Persians all contain sections on animals, plants, and stones. The best known is that of Zakariyyā al-Qazwīnī (d. 1283) still imperfectly edited. Many manuscripts of this work are beautifully illustrated.

There exists a considerable number of books and sections of encyclopaedias dealing with the subject of physics, most of them from a philosophical point of view.

Metrological studies were much in favour with the Muslims of the later centuries, particularly those on balances. Al-Khāzīnī, originally a Greek slave who lived about 1200 in Merv (Persia), left a voluminous book The Balance of Wisdom, of which parts only have been edited. He takes up and continues Thābit b. Qurra’s investigations of the so-called ‘Roman’ balance, or steelyard, which is itself of Greek origin. His work comprises, moreover, valuable remarks on specific gravity and the specific weight of alloys. Khāzīnī also dealt with the problem of the greater density of water when nearer to the centre of the earth, shortly before Roger Bacon propounded and proved the same hypothesis.

Very fine manuscripts, full of good illustrations, exist on hydrostatic automata and on clocks, particularly such as were moved by water, mercury, weights, or burning candles. Al-Jazā’rī finished, in 1206, in Mesopotamia, a great book on mechanics and clocks, the best extant in the Islamic world. At the same time (in 1205) the Persian Ḫājīwān described the water-clock constructed by his father Muḥammad ibn ʿAlī near one of the gates of Damascus, an artifice much admired throughout the Islamic world, the memory of which survived until the sixteenth century. The authors refer to Archimedes, Apollonius, and

Kresibius, but are remarkable in their exact description of all the mechanical details.

Prominent in optics was the Persian Kamāl ad-Dīn (d. about 1320). He repeated and improved on Alhazen’s experiments with the camera obscura (p. 335). He also observed the path of the rays in the interior of a glass sphere in order to examine the refraction of sunlight in raindrops. This led him to an explanation of the genesis of the primary and secondary rainbows.

A curious example of the lively interest shown by laymen in scientific questions is seen in the optical book of Shīhāb al-Dīn al-Qarāfī, a theologian and judge in Cairo (d. c. 1285). He discusses—in a more speculative than scientific manner—fifty optical problems, three of which are of special interest because they concern questions put to Muslim scholars by ‘the Emperor the king of the Franks in Sicily’. This was no other than Frederick II of Hohenstaufen who between 1220 and 1230 set philosophical and geometrical problems for Muslim scholars in Spain and Egypt. The three questions on optics are: Why do oars and lances, partly covered with water, appear to be bent? Why does Canopus appear bigger when near the horizon, whereas the absence of moisture in the southern deserts precludes moisture as an explanation? What is the cause of the illusion of floating specks before the eyes of those suffering from incipient cataract and other eye trouble?

Finally we must cast a glance at two bio-bibliographical works of high importance for the history of Islamic medicine and science. First the History of Philosophers by Ibn al-Qīṭī (d. in Damascus 1248), containing 414 biographies of Greek, Syrian, and Islamic physicians, astronomers, and philosophers. It is a mine of information for the knowledge of Greek literature possessed by the Arabs and it tells us much about Greek antiquity which has not survived in classical sources. No less important is the Valuable Information on the Classes of Physicians by Ibn Abī Uṣaybiʿa, a very learned physician
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and oculist who lived chiefly in Cairo (d. 1270). He deals with the life and work of more than 600 medical men, taking his information partly from works now lost, partly from his intimate knowledge of many thousands of medical books. All the modern histories of Arabian medicine are based on this work, which also contains valuable classical traditions.

The dependence of the Copts in Egypt, and the Armenians, on Arabic medical science is evident from such of their works as are available in modern dress. Lack of space prevents the author from giving an analysis of them.

§ 5. The Legacy

We turn now from the storehouse of Arabic science to its passage to the West. The legacy of the Islamic world in medicine and natural science is the legacy of Greece, increased by many additions, mostly practical. Rhazes, the Persian, was a talented clinical observer, but not a Harvey. 'Abd al-Latif, the Arab, was a diligent seeker in anatomy, but in no way to be compared to Vesalius. The Muslims possessed excellent translations of the works of the Hippocratic Corpus and of Galen. All, even the long theoretical explanations of the latter, were well understood and well rendered by such intelligent and polyglot scholars as Hunayn. But the additions of the Islamic physicians refer almost solely to clinical and therapeutic experience. The theory and the thought of the Greeks were left untouched and treasured up after careful systematization and classification. It must be remembered that Muslims were strictly prohibited from dissecting either human bodies or living animals. Thus experiment was practically impossible in medicine, so that none of Galen's anatomical and physiological errors could be corrected. On the other hand, they received some impetus from the experience of Persian, Indian, and Central Asian scholars concerning particular lines of treatment, operations, and the knowledge of drugs and minerals. This knowledge helped them to make progress in chemistry, although we are, as a matter of fact, not yet sufficiently informed to be able to state what is the share of Greece and what that of the Orient in the development of alchemy.

In other sciences some of the best Greek works were unknown to the Muslims, as, for example, the botany of Theophrastus. Their own share in this branch is a considerable one, but again, of purely practical importance. The Muslim scholars, although acute observers, were thinkers only in a restricted sense. It is the same in zoology, mineralogy, and mechanics. The glory of Muslim science is in the field of optics. Here the mathematical ability of an Alhazen and a Kamâl al-Dîn outshine that of Euclid and Ptolemy. Real and lasting advances stand to their credit in this department of science.

When Islamic medicine and science came to a standstill, about 1100, they began to be transmitted to Europe in Latin translations. The state of monkish medicine at that period is vigorously described by Charles Singer in his Short History of Medicine: 'Anatomy and Physiology perished. Prognosis was reduced to an absurd rule of thumb. Botany became a druglist. Superstitions crept in, and Medicine deteriorated into a collection of formulae, punctuated by incantations. The scientific stream, which is its life-blood, was dried up at its source.'

Only in one corner of Europe, at Salerno near Naples, a medical school preserved some traces of Greek medicine, and it was here that the Tunisian adventurer and renegade, Constantine the African, passed several years before he became a monk at the famous convent Monte Cassino in Campania. There he took up the work of translation about 1070 to continue it until his death (1087). Constantine's Latin versions are corrupt, confused, full of misunderstood Arabic terms, in parts incomprehensible, the true prototype of the Barbaro-Latin literature of the Middle Ages. But they had the merit of planting the first
sparse seed of Greek learning in the sterile soil of medieval Europe.

Constantine was a shameless plagiarist claiming for himself many works which he had translated from Arabic into Latin. We may, however, remember that the rights of authorship were but lightly regarded in those times. He translated into Latin Hippocrates' Aphorisms from Ḥunayn's Arabic version, with Galen's commentary from Ḥubaysh's version; Hippocrates' Prognostica and Dietae Acutorum; together with many works of Galen. The fate of one book issued as Constantine's De Oculis is characteristic of the times. It was later turned again into Latin by a certain Demetrius, perhaps in Sicily. In reality it is nothing but Ḥunayn's book The Ten Treatises on the Eye. Constantine was, however, the first to render Greek scientific works accessible. He also placed the works of Ḥaly Abbas and Isaac Judaeus in the hands of his successors. The alchemical Liber Experimentorum of Rhazes was translated into Latin by Constantine, who had disciples among the monks of Monte Cassino. One of these was Johannes Asclacius 'the Saracen', who helped him in the translation of Arabic works into Latin.

During Constantine's lifetime the struggle between Christendom and Islam was active both in Spain and in Sicily. In 1085, Toledo, the greatest centre of Muslim learning in the West, fell before the Spanish Christians. Latin students began to come to the new capital to admire the remains of Moorish civilization and to study the Artes Arabum. The intermediaries for the learning and later on the translation work were native Jews and former Muslim subjects (Mozarab). Charles and Dorothea Singer, in another volume of this series, have painted a lively picture of this collaboration, which gives a clear idea of a curious scientific syncretism. The first prominent European man of science who came to Toledo was Adelard of Bath, an English mathematician and philosopher. On the other hand a Spanish

Jew converted to Christianity, Petrus Alphonsi, went to England where he became physician to Henry I and spread the science of the Musulm there for the first time. Both scholars translated Arabic astronomical and mathematical works into Latin during the first half of the twelfth century. Many others followed their example.

The scientific life which expanded in Toledo during the twelfth century is reminiscent in many ways of the translation period of Baghdaḍ three centuries before. Just as the Caliph al-Ma'mūn installed the 'House of Wisdom', so Archbishop Raymond founded, under the direction of the Archdeacon Dominico Gundisalvi, a school of translation which flourished in Toledo until the thirteenth century. The part of the polyglot Christian and Ṣābīan translators of Baghdaḍ was played in Toledo by the Jews who spoke Arabic, Hebrew, Spanish, and sometimes Latin. The converted Jew Avendeath (Ibn Dawd, i.e. son of David) translated a great many mathematical, astronomical and astrological works of the Arabs into Latin, as the Ṣābīan Thābit ibn Qurra had turned those of the Greeks into Arabic. Gerard of Cremona did for the Latins what Ḥunayn ibn Iṣḥāq did for the Arabs in translating the works of philosophers, mathematicians, physicists, and physicians.

Gerard, born in Cremona in Italy in 1114, came to Toledo to find Ptolemy's Almagest. He translated it into Latin in 1175. He soon became the most prominent and prolific of all the translators from Arabic, being helped in his task by a native Christian and a Jew. In the two decades before his death in 1187 he produced nearly eighty translations, some of them of the utmost importance. By opening wide the doors of the treasure-house of Greek and Arabic learning, at the same time he gave many followers the impulse to imitate his example. He is the real father of 'Arabism' in Europe.

In medicine we owe to Gerard versions of the works of Hippocrates, of Galen, of nearly all Ḥunayn’s translations, of
works of al-Kindi, of Avicenna’s vast *Canon*, and of the important and influential *Surgery* of Abulcasis. In physics he rendered from the Arabic many of the works of Aristotle, including the apocryphal *Lapidary* ascribed to the great philosopher, as well as writings by al-Kindi, al-Farabi, Isaac Judaism, and Thabit.

Mark, Canon of Toledo, perhaps a younger contemporary of Gerard, also did good service. He translated the treatise on *Airs, Waters, and Places* of Hippocrates and many works of Galen, all from Ḥabayah and Ḥunayn’s Arabic versions. Ḥunayn’s famous *Qaestiones medicæ* were translated by Rufino, a scholar of Alessandria in Italy who lived at Murcia in Spain. Abraham, a Jew of Tortosa, helped Simon of Genoa (*Jamaensis*) to translate Abulcasis’ *Liber Servitoris* and Serapion the Younger’s *De Simplicibus*.

Other portions of Abulcasis’ output were translated by a certain Berengar of Valencia, and by Arnold of Villanova (d. c. 1313). The latter is the last renowned medical translator of Spain. We owe to him the versions of works of Avicenna, al-Kindi, Avenzoar, and others.

Sicily, which had been under Muslim control for 150 years, fell definitely into the hands of the Normans in 1091, and became a fertile centre for the spread of Arabic science. Among the population Greek, Arabic, and Latin were in constant use as vernacular dialects, but some scholars, particularly Jews, also knew the literary form of these languages. The kings, from Roger I to Frederick II, Manfred, and Charles I of Anjou, drew learned men to Palermo regardless of language or religion. Here, as in Toledo, a troop of learned translators began to make Latin versions from Greek and Arabic. These translations mainly dealt with astronomy and mathematics.

In medicine no important translations were accomplished in Sicily during the twelfth century. In the following century, in the reign of Charles of Anjou, however (1266–85), we meet the great Jewish translator ‘Farragut’ of Girgenti and his translation of Rhazes’ *Continens* (p. 324). He finished his task, which would have occupied half a normal lifetime, in 1279.

Another Jew, Moses of Palermo, was trained as a Latin translator at the order of King Charles. Of his works we know only the version of a pseudo-Hippocratic work on the diseases of horses. Michael Scot (d. 1235), favourite of Frederick II, translated into Latin from Arabic and Hebrew versions the entire biological and zoological works of Aristotle, particularly the abstract of *De Animalibus* with Avicenna’s commentary which he dedicated to the emperor in 1232.

It is well known that Frederick II exhibited great interest in zoology, that he used his wealth and his friendly relations with Muslim rulers to keep a menagerie of elephants, dromedaries, lions, leopards, falcons, owls, &c., which he then took with him on his travels. The emperor himself wrote a work on hunting, *De Arte Venandi*, largely based on a work of Michael Scot, and on the same scholar’s translation of Aristotle’s zoology. (With regard to Frederick’s interest in optical questions see p. 343.)

The influence of the Crusades on the transmission of the Islamic sciences to Europe was surprisingly little. The only important work we can trace to that movement was by a certain Stephen of Pisa, who was trained in Salerno and in Sicily. He came to Antioch and translated there in A.D. 1127 the *Liber regalis* of Haly Abbas. In it he severely criticizes the former translation of the same work made by Constantine the African.

We may suppose that the foundation of hospitals throughout Europe during the thirteenth century, hospitals which were no longer under clerical supervision alone, was partly due to the influence of the Crusades. They may well have been imitations of such splendidly installed *Bimarists* as that of the contemporary Seljûq ruler Nür al-Din in Damascus, and that of the Mamlûk sultan al-Manṣūr Qâlawûn in Cairo. The latter institution was much admired by European travellers of later
centuries, and after a period of decay has seen a renaissance in our time. In Italy Pope Innocent III founded in Rome at the beginning of the thirteenth century the Hospital San Spirito from which a network of kindred institutions soon spread over western Europe. The asylum and hospital ‘Les Quinze-Vingts’ was founded in Paris by Louis IX after his return from his unhappy crusade in 1254-60. Originally intended for three hundred poor blind men, it had added to it later a hospital for eye-diseases which is now one of the most important in the French capital.

The Muslims who came in touch with Frank physicians during the Crusades expressed much scorn for their professional skill. This appears for instance from anecdotes related by the Syrian prince Usama based on the reports of his Arabic Christian physician Thabit. This man about A.D. 1140 observed two cases which ended fatally owing to the barbarous surgery of a Frank.

Some of the Latin translators worked in northern Italy. Here, for instance, Burgundio of Pisa had made translations of ten Galenic works direct from the Greek (c. A.D. 1180). Accursius of Pistoia translated Galen’s De Viribus Alimentorum from Hubayh’s Arabic version about 1200; the Jewish convert Bonacosa translated Averroes’ Colliget into Latin in Padua in 1255, and Paravicius rendered Avenzoar’s Tayyir in Venice, with the help of the Jew Jacob, in 1280.

Of other translators the period and origin are unknown, as for example, of David Hermenus who translated Canamusali’s ophthalmology. Many works too are extant in Latin translations by anonymous authors, among them being treatises by Maimonides, Avicenna, Geber, Rhazes, and Alhazen. We note particularly that most of the alchemical writings are anonymously rendered.

The process of translation went on well into the sixteenth century. Thus Andrea Alpago of Belluno in Italy (d. 1520)
wounds. For some time in northern Italy the non-suppurative treatment of wounds with wine-compresses was practised.

Natural science had its home in the University of Paris. The Aristotelian science as introduced from Toledo with Averroes' commentaries was the foundation of learning. Roger Bacon and his scientific opponent Albert of Bollstaedt (Albertus Magnus), among others, here expounded the works of the great Muslim scientists. We have already seen how Roger Bacon's Optics was based on Alhazen's *Thesaurus Opticæ*. Albert repeated the alchemical teachings of 'Jabir' (Geber) and other Arabic writers in his *De Mineralibus*. He is original only in his zoological and botanical studies, and even in these he relies greatly on translations from Arabic. The influence of Geber is very pronounced in the encyclopaedia *Speculum Naturale* by Vincent de Beauvais. The alchemical tracts ascribed to Arnald of Villanova and to Raymund Lull are full of quotations from Geber. Arabic alchemy, associated as it was with astrology, predominated throughout the thirteenth and fourteenth centuries.

After the sixteenth century medicine and science, particularly in northern Italy, begin to refer more and more to translations from the Greek rather than the Arabic. 'Hellenism' was opposed to 'Arabism', though there was no fundamental difference between them. As long as the books of the Ancients formed the almost exclusive basis of scientific research, Scholasticism maintained its supremacy. After the invention of the art of printing, in the second half of the fifteenth century, all the Graeco-Arabic works on medicine and science were eagerly and repeatedly printed. It was in the period 1530 to 1550 that Arabism received its death-blow. Simultaneously with the revolution of astronomy by Copernicus (d. 1543), Paracelsus (d. 1541) reformed alchemy and medicine, and incessantly urged his students to abandon Galen and Avicenna and to return to the observation of nature: *Experiments et ratio auctorum loco mihi suffragantur!* In the same year, 1543, in which Copernicus published his *De Revolutionibus Orbium coelestium*, Andreas Vesalius edited his fundamental new anatomy. This year marks the end of the Middle Ages in medicine and science and with it the effective end of the direct influence of Arabian science.

Still Arabism lingered on. In Vienna in 1520, and in Frankfurt on the Oder in 1588, the medical curriculum was still largely based on Avicenna's *Canon* and on the ninth book *Ad Almansorem* of Rhazes. Even in the seventeenth century in France and Germany some scholars kept to Arabic erudition, whilst the struggle between Hellenists and Arabists went on in northern Italy until both were crushed by the advent of the modern scientific method. Arabic pharmacology survived until the beginning of the nineteenth century. Parts of the Latin version of Ibn al-Baytār's *Simplicia* were printed as late as 1758 at Cremona; Serapion and Mesu the younger were studied and summarized for the use of European pharmacopoeias until about 1830. The Armenian compilation of medicine from Greek, Arabic, and Persian sources composed by Mechitar in A.D. 1184 was reprinted in Venice in 1832. In an old German treatise on zoology of 1838 I have found all the legends relating to the poisonous nature of the gecko—a harmless oriental house-lizard—which are to be read in ad-Damiri's *Life of Animals*.

In certain branches of medicine the Graeco-Arabic tradition survived long, even in practice. Vesalius himself left several errors of Galen and Avicenna concerning the anatomy of the eye unchanged, and they were not corrected before c. A.D. 1600. The real nature of cataract as a solid opacation of the lens, not as a congealed liquid, was discovered by Pierre Brissaus, a French practitioner, in 1604. And the oldouching operation for cataract, with a needle, as described by Antyllos of Alexandria and as handed down by Rhazes and 'Ali ibn 'Isā, was still practised by Percivall Pott in England about 1780, and in Germany even as late as 1820.
In the Islamic Orient the old scientific and medical tradition is still fully alive in popular medicine and among village barbers. The author saw in Cairo, on the very day on which he wrote these lines, a man operated on for cataract by a wandering Sudanese charlatan in accordance with the directions of Antyllus and Avicenna. The native druggists from Morocco to India habitually compose their remedies in accordance with the Agrabaddins (p. 338) of the Arabic physicians.

Looking back we may say that Islamic medicine and science reflected the light of the Hellenic sun, when its day had fled, and that they shone like a moon, illuminating the darkest night of the European Middle Ages; that some bright stars lent their own light, and that moon and stars alike faded at the dawn of a new day—the Renaissance. Since they had their share in the direction and introduction of that great movement, it may reasonably be claimed that they are with us yet.

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SOME BOOKS OF REFERENCE

This article should be read in conjunction with that by C. and D. Singer on ‘The Jewish Factor in Medieval Thought’ in The Legacy of Israel.

1. ARABIC MEDICINE AND SCIENCE.