Indian Journal of History of Science, **21**(3) : 261–269 (1986)

IBN SĪNĀ AS A SCIENTIST

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It has often been held about Ibn Sīnā that he was a theoretician and that what he wrote belongs, for the most part, to the realms of philosophy (mainly ontology and metaphysical speculation), theory of temperament, music, *etc.* Nothing could be farther from the fact, as we propose to show.

MUSIC

Ibn Sīnā was the first scientist and physician to elaborate upon the theories of music propounded earlier by al-Kindī (9th century) and al-Fārābī (10th century).

Ibn Sīnā came out with the theory of musical therapy in keeping with the temperament of the patient. In other words, music was employed for soothing the patient's nerves—a far better method than the administration of tranquillizer with their side-effects.

GEOLOGY

Ibn Sīnā's discussion of geology and mineralogy had gained international fame shortly after his death. Alford of Sareshel, an Englishman (about A.D. 1200), less than two hundred years after Ibn Sīnā's death, translated part of the section concerning mineralogy and geology into Latin under the title *De Mineralibus* directly from the Arabic. This aspect has been discussed in detail by Holmyard and Mandeville in their French work, *Avicennae de Congelatione* (congelatio in medieval Latin stands for solidification). Al-Bīrūnī also describes a comet and the process of stone-formation but, while the former only narrates what he had seen or heard, Ibn Sīnā has the better of him in that he makes certain inference. For example, Ibn Sīnā attributes the formation of stones to two processes : formation of porous refractories, and regular solidification(*jamūd*),whence follows the word *jamādāt* or mineral deposits. He seems to have known the aggregating or agglutinative properties of clay, since he holds that stones may be formed out of flowing water, either through the process of solidification as the water falls drop by drop (here he is obviously referring to stalactites, composed of calcium carbonate) or during its flow in the form of stalagmites on the floor of caves. Another way in which this petrification process might occur is through the deposition of things upon the river bed and subsequent petrification. Ibn Sīnā illustrates the occurrence of the last process through a personal observation. He relates he had seen deposits of lime with which people washed their hands, presumably because it contained sodium carbonate (we must note that the classification of elements and the discovery of their compounds crystallized towards the end of the 18th century), along the banks of the Oxus river, where he spent his childhood. Twenty years later, these deposits had solidified into stone. Just as before the time of Joseph Priestly, the discoverer of oxygen, and until as late as mid-18th century, this element, oxygen, went by the name 'phlogiston'. Ibn Sīnā ascribes the different colours of pebbles formed out of water to the mineralizing, solidifying "element of earthiness" in them. He also knew of the process of coagulation, for he says this "earthiness" becomes predominant, as with salt when it undergoes the process of coagulation. He says, with great prescience, that this is a characteristic that does not depend upon quantity. The reason for the coagulation may be contact with heat, "or it may be", says Ibn Sīnā, "that the virtue is yet another, unknown to us".

Ibn Sīnā was also aware of chemical reactions. He thus speaks of two liquids which, when mixed, produce a white precipitate which is called Virgin's Milk. It is not impossible—here he again shows the same prescience—for compounds to be converted into a single element, if that element becomes preponderant and converts the others into its like. This is how things that fall into fire are converted into fire. The rapidity or slowness of conversion depends on the nature of the elements. He is, of course, speaking in the language of the four-element theory here, but obviously he is using elements symbolically.

The formation of a large stone is attributed by Ibn Sīnā to its occurrence all at once through the effect of intense heat suddenly turned upon a large mass of clay, or gradually with the passage of time. Like Aristotle, he rather erroneously believes that it is winds that produce earthquakes, but he is absolutely correct when he says that these sometimes lead to the formation of hills. Erosion caused by wind and floods is an accidental cause and this is how valleys and deep depressions come to be. While he follows the Greeks in believing that the world was submerged underneath the ocean, he goes further than the Greeks when he says that through exposure it might have petrified a little, and the process of petrification might have been due to the exposure of the earth with the assistance of the agglutinative clay. This is why certain stones, when broken, have the fossilized bodies of some aquatic animals formed in them.

Soheil M. Afnan in this context says :

> "The Greeks also had observed that sea-shells are sometimes seen in regions far from the sea ; but orthodoxy would not concede the idea that all or certain parts of the earth might have been at one time covered by water, until Leonardo da Vinci correctly affirmed it".

In other words Ibn Sīnā, five hundred years earlier, had anticipated Leonardo da Vinci. Ibn Sīnā offers explanations for some of the natural phenomena detailed below.

The reddish and black marks that present a dreadful appearance around the discs of certain stars are gases that have caught fire because of their constant motion (*i.e.* the heat generated leads to ignition). Also, when these gases are very dense and tend to trail behind a star, the fire burns furiously, forming a tail to it. This is how the comets have come into existence. The halo is caused by the reflection of the light passing through clouds around the luminary.

Meteorology

Ibn Sīnā has offered explanations for certain meteorological phenomena. Winds, for example, lose their moisture and become warm when they pass over hot land. Water vapour that gets trapped in the earth condenses into water, and finally rises again in the form of fountains. Winds are formed when certain regions are hot and others are cold, and cyclones occur where violent winds meet each other and then start turning round.

Ibn Sīnā seems to have been aware that oil is formed under high pressure underneath the earth which is the basis of Engler's theory of the formation of petroleum. He observes that certain gases, when trapped in the earth, form different minerals and metals, according to the place and the time involved, *e.g.* gold, silver, mercury, and oil.

As regards air, he says he has himself observed it suddenly thicken and change, partially or entirely, into rain, hail, or snow, and then clear up again. He had seen it turn into clouds or into mist covering mountain summits, or even the surface of the plain because of the cold. Frost forms on cold nights. These phenomena, he holds, are obviously not due to the water present in the air being attracted towards itself as a result of the cold, because water by nature can move downwards only. Air and water, according to him, have a common denominator, and water by the process of evaporation turns into air.

Ibn Sīnā seems to have been aware of the force of compression. He says that when air is violently agitated, it develops burning property. (Here he anticipates the "phlogiston" theory, and the discovery of oxygen 700 years later). Men, he says, therefore make use of this property of the air by devising special instruments like bellows. Air can ignite wood and other inflammable objects and fire therefore is nothing except a property to ignite.

While discussing the properties of air he adds that elements are derived from each other, and the corruption of one element leads to the corruption of another.

There is alteration and transformation in them when there is a change in quality. When this happens, "the disposition for the form most suited to it changes, and therefore it takes a new form". Clouds are formed when water vapour rises very high and the cold of the upper regions turns it into clouds as rain. When it settles down over the land and is visited by the cold of the night, it is turned into dew. When the clouds freeze, we get snow; but, if they turn into rain and then freeze, we get hail.

Another major contribution of Ibn Sīnā is his total discredit of alchemy. In this respect he is the equal of Francis Bacon in heralding an inductive approach to science. The practice of alchemy had penetrated so deeply into the fabric of Muslim science that even al-Kindī and Abū-Naṣr Fārābī had argued that it was a legitimate pursuit.

Mathematics and Astronomy

In the *Kitāb al-Shifā'* (*Sanatio*), after a section on plants and another on animals, corresponding to what Aristotle had written about them, Ibn Sīnā has given a number of *fanns* (chapters) concerning mathematics. Ibn Sīnā wrote a commentary on the *Elements* of Euclid and the principles of geometry. In a complete section, one of the more original ones in astronomy, he gives his views about *Almagest* of Ptolemy and the new observations that he thought ought to be added to those of Ptolemy for their deficiency. He was also engaged in writing a summary of *Almagest*.

Ibn Sīnā's contribution to natural science was more theoretical, and, as Sarton has said, what we should expect in a Neo-Platonist. And yet in his approach to the subject, he is very original. He explains, for example, the casting out of nines and its application to the verification of squares and cubes. He made astronomical observations towards the end of his life at Hamadan, and devised a measuring contrivance for the purpose, which was very similar to the vernier, to increase the precision of reading.

Chemistry

Regarding mineral substances and their properties, he divides mineral bodies into four groups, *viz.*, stones, fusible substances, sulphurs, and salts. Some of these are weak, while the others are strong. Here Ibn Sīnā anticipates the principle of chemical affinity; some are malleable (*i.e.* metals), while others are not (non-metals); some have the nature of salt, while the others are oily. He then details the properties of some of the minerals.

It is true that most of his chemistry follows the pattern conventional in his time, and yet what distinguishes him from his predecessors and contemporaries is his firm opposition to alchemy. More research will have to be done upon the chemistry of Ibn Sīnā, but we might perhaps note that minerals correspond to inorganic substances and the oily substances to organic chemicals, perhaps oleoresins and essential oils.

Physics

Ibn Sīnā did not formulate any specific physical law, but he did make profound observations upon some important physical questions, *e.g.*, motion, contact force, vacuum, infinity, light, heat, and so on. He makes the observation, for example, that if the perception of light is due to the emission of some sort of particles (an anticipation of the various components of light ?) by the light-source, the velocity of light has to be finite. Like his great contemporary, he also made investigations on specific gravity.

Medicine

As for Ibn Sīnā's contribution to medicine I propose to divide this subject into the following parts: (i) contribution to anatomy, (ii) contribution to the theory and philosophy of medicine, (iii) investigations upon the properties of drugs, and (iv) influence upon posterity.

Contribution to Anatomy

Despite the fact that Galen experimented upon monkeys, his anatomical observations are remarkably comprehensive, and his work on the spinal cord justly entitles him to be remembered as the father of experimental physiology. Ibn Sīnā followed Galen, but made certain improvements, *e.g.*, in his definition of simple and compound organs. Organs are either simple or compound. Simple organs are those in which the visible and perceptible parts carry the same name and definition as the whole organ, *e.g.*, flesh, nerves, *etc.* Simple organs are called homogeneous, as their tissue particles are of the same type. Although the knowledge of the cellular structure of organs was not known then, this statement is broadly speaking correct even today. Among the simple organs Ibn Sīnā classifies bones, cartilage, nerves, tendons, connective tissues, arteries, veins, membranes, and flesh. On the other hand, compound organs are those whose comprising parts, irrespective of size, differ in nature as well as in name, *e.g.*, hand, foot, and face. A part of the face cannot be called the face or a part of the hand the hand.

Organs are evolved from the heavier portions of humours, varying in size, shape, and relationship. Each organ has its own characteristic structure and temperament, in consonance with its functions. Heart is thus hot and dry, liver hot and moist, bone cold and dry, brain cold and moist. They can be vital or subsidiary and interconnected through afferents or efferents, receptors or effectors. The overlapping of such activity in the vital organs extends their functions far beyond their anatomical borders.

Ibn Sīnā therefore regards anatomy not only the basis of medical studies, but deems it essential for the performance of surgery and cure of internal disorders. His description of the heart and blood vessels records an improvement over that of Galen. Some of his notable advances in this field are the unidirectional flow of blood, with movements to and from the heart and the presence of anastomoses between the minute branches of veins and arteries which Robert Harvey 550 years later failed to recognize. One of the errors committed by Ibn Sīnā, however, is that he had regarded the origin of the pulmonary artery from the left heart and the presence of a hole in the septum. This error was, however, rectified by Ibn-al-Nafis Qarshi (*d.* 1289), who advanced the hypothesis of the pulmonary circulation of blood.

Contribution to the Theory and Philosophy of Medicine

In *al-Qānūn fiṭ-Ṭibb* or the *Canon* Ibn Sīnā defines medicine as the knowledge of human body, in health and decline of health: its aim is to preserve health and endeavour to restore it when it deteriorates. His medicine is much more than the physic of ancient Greeks and the science and art of diagnosis, treatment, and maintenance of health of the modern Western medicine.

As against the speculative approach adopted by Galen, Ibn Sīnā follows the principle that knowledge of a material object can be obtained only by determining its origin and causes, provided that its origin is accessible to observation. When this is not so, knowledge should be gleaned from symptoms. Deriving his basic hypotheses from physics, he laid the foundation of solid anatomy and organic physiology through observation and analysis of organs and their functions. He laid special emphasis upon the knowledge of health (where the temperament is equal and the humours are proportionately present) and disease (where this is not so), symptoms and methods of preserving and restoring health (by means of inductive reasoning). He went further and inferred, although not obvious, from signs and symptoms with reference to both space and time, data about health and disease. He observes in the *al-Qānūn*:

> Matters which have to be recognized by observation and analysis are the organs and their functions. Matters which have to be learnt and proved by reason are: (a) diseases; (b) their special causes; (c) symptoms; and (d) methods of preserving health and eradicating disease. Of these there are some matters which are not obvious and have to be fully described with reference to quantity (space) and time and explained with reasons.

Ibn Sīnā added new knowledge through the exercise of reason and experiment under controlled conditions, especially the latter. He tested the purity of substances, *e.g.*, water, by comparing them with acceptable norms. He kept a voluminous record of cases for transcription, but it has been reported lost during flight from enemies. He advocates experiment when the physician is not sure whether the cause of a disease is hot or cold. While carrying out such an experiment, powerful drugs should be avoided, and care exercised to ensure that during the experiment side effects of the drug do not mask the true picture. Although the cooling and warming processes take almost the same time, cold, according to Ibn Sīnā, is apt to be more dangerous because heat after all is akin to life. He further makes the following observation :

> ......The side effects of moisture and dryness are almost in equal intensity but the former takes a much longer time to act. Moisture and dryness are maintained by supporting the causative factors and altered by counteraction. Heat is strengthened by supporting the factors already mentioned and increased by dispersing plethora and removing obstructions...

This section of the first volume of the *al-Qānūn*, dealing with the treatment of abnormal temperaments, is among the most important in the history of medicine.

As against the Galenic concept of the four temperaments namely sanguine, choleric, phlegmatic, and melancholic, Ibn Sīnā formulates hot-moist, hot-dry, cold-moist, and cold-dry temperaments. Such a concept is obviously superior to that of Galen because, while according to Galen's concept the temperaments remain static, they do not do so according to Ibn Sīnā. Thus children and the youngs are stated to be hot, with the children inclined towards a greater degree of moisture and the young ones to a greater degree of dryness. The middle-aged and elderly are cold and dry, but the senile ones are cold and moist. Blood is hot and moist ; bile hot and dry ; phlegm cold and moist ; and atrabile cold and dry.

Ibn Sīnā relates the dominance of each humour to its characteristic colour and qualities and to the age and temperament of the patient, the nature of his food, the tempo of his activity, and the prevailing season.

Once the excess of a given humour has been arrived at, the humoral balance has to be restored. According to Ibn Sīnā the quickest and best method for rectifying the excess of blood-humour is venesection, while specific eliminants such as scammony for bile, colocynth for phlegm, and senna for atrabile are employed to clear the excess of other humours.

Properties of Drugs

Just as every individual has his own temperament, drugs are also characterized by their own physical characteristics. When we speak of a drug as being hot, cold, dry, and moist, it means that after its action and reaction within the body, it produces a perceptible degree of heat, cold, dryness, or moisture in the body. Drugs are graded according to the Galenic degree. Thus, if a drug is denoted by C3 D1, it means that it is cold to the third degree and dry to the first degree. The fourth degree is the maximum.

Ibn Sīnā in his Materia Medica (V 91. II of the *al-Qānūn*) has described 760 drugs. Some of the drugs, like *faghirah* (*Zanthoxylum budrunga* Wall.) and *mishk-i-tara-mashih* (*Ziziphora tenuior* L.) are new additions to the Greco-Arab materia medica. He grades each drug according to its Galenic effect.

Volume V of the *al-Qānūn* describes special prescriptions and theriacs (antidotes). Ibn Sīnā describes methods for the preparation of pills, powders, syrups, decoctions, confections, elixirs, *etc.* Prescriptions for different diseases have been given and weights and measures provided. A part of this volume was translated by Sontheimer, who also translated the materia medica of Ibn al-Baytār in 1845.

Influence upon Posterity

The *al-Qānūn* was translated by Gerard of Cremona into Latin in the 12th century. It attained such popularity in the last thirty years of the 15th century that it was issued sixteen times and thirty times during the 16th. This is, of course, exclusive of the publication of separate parts of the voluminous work. Even in the second half of the 17th century—in the age of Harvey—it was still being printed and read, and used by practitioners. It was being studied as a text-book in the medical school of Louvain University as late as the 18th century.

Among his contributions to practical medicine is his introduction of some new drugs. He seems to have been the first physician to have realized the antiseptic effects of alcohol, for he recommends that wounds should be first washed with wine. But perhaps his greatest contribution was the new theory of temperament and the theories he put forward with regard to the interchangeability of heat, cold, dryness, and moist, and the restoration of humoral balance. Greco-Arab medicine cannot just survive without him, he being rightly called the *Shaykh al-Ra'īs.*

We must consider Ibn Sīnā's contribution to science according to the age in which he lived. When we speak of the contributions that Newton, Galileo, Darwin, Leibnitz and others made to science, we should bear in mind the fact that through a greater degree of dissemination of knowledge with the aid of the printing press, heaps of data accumulated and out of these data universal laws and principles emerged. The first elements, hydrogen and oxygen, were not discovered before the 18th century, and even during the Renaissance period magic rather than experimental science was held in honour. A perceptive historian of science, the late A. R. Hall, in this context observes:

"...... The cosmos of Shakespeare is the cosmos of Dante, save that the former was a far less philosophical poet: the Fables of Bartholomew, the complex

> vocabulary of astrology and alchemy, and the doctrine of the four humours still enclosed the frame-work of science which most men knew. It was not the experimentally minded Dr. William Gilbert, with his glass rods, magnetic needles and other trivia, who was most honoured at the Court of Elizabeth, but Dr. John Dee, the astrologer and magus, holding, as it seemed, the keys to far graver mysteries." [*The Scientific Revolution* (1500—1800), p. 72]

Today the margin of error in the formulation of laws is far less than it was a thousand years ago since far more data are available. If Engler's view regarding the origin of petroleum through the decomposition of the fossilized under high pressure is accepted as correct, this is because we know that high pressure leads to polymerization and because of our knowledge regarding decomposition and what compounds would form under given circumstances. We also know of the different geological epochs and have at our disposal the data that would enable us to determine their ages.

None of all these was available to Ibn Sīnā—no mirrors to reflect in order to determine the speed of light. Nor did he have any leisure, for his life was spent in wandering far from his homeland in Bukhara. He himself has said :

> And great once I became, no more would Egypt have me.
> And when my value rose, no one would care to buy me.