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(*b*. Edinburgh, Scotland, 3 June 1726; *d*. Edinburgh, 26 March 1797)

geology, agriculture, physical sciences, philosophy.

Hutton was the only son of William Hutton, a merchant and former city treasurer in Edinburgh, and Sarah Balfour, daughter of John Balfour, another Edinburgh merchant, whose descendants provided two professors of botany at Edinburgh University. William Hutton died in 1729 when James was three years old. His will indicates that he left the family, including Hutton's three sisters, quite well-off, and apparently Hutton was never under any pressing need to earn a living. He attended Edinburgh High School and in 1740 entered Edinburgh University as a student of the humanities. He attended the lectures given by John Stevenson on logic and rhetoric and those of the mathematician Colin Maclaurin, which included physics, experimental philosophy, and geography as well as mathematics.

It is said that Hutton enjoyed Maclaurin's lectures particularly, but his biographer John Playfair[1] states that it was to Stevenson that Hutton was indebted for his interest in chemistry, as a result of an experiment introduced into a lecture. Little information about chemistry was then available to Hutton, but he retained and developed his interest in the subject throughout his lifetime.

On leaving the university it was apparent that Hutton had an inclination for academic studies, but he was persuaded to follow an occupation more likely to provide a professional career. Consequently, in 1743 he was apprenticed to an Edinburgh lawyer. The routine of a lawyer's office was not to his liking, and he was soon released from his obligations. He then decided to study medicine, the only professional course which ensured that he would learn something more about chemistry. He reentered the university in 1744, and studied medicine there until 1747, probably attending the lectures of Andrew Plummer, professor of medicine and chemistry, who had studied under Boerhaave.

Toward the end of 1747 Hutton went to Paris, where he remained nearly two years. There, according to Playfair, "he pursued with great ardour the studies of chemistry and anatomy." Because of his interest in chemistry, he probably attended G. F. Rouelle's well-known and popular chemistry course, which also included lectures on mineralogy and geology. Thus it was possibly in Paris that Hutton first became acquainted with geology. Sometime during 1749 Hutton moved to Leiden, where he graduated M.D. in September of that year with a thesis entitled *De sanguine et circulatione microcosmi*.

After leaving Leiden at the end of 1749 Hutton spent several months in London. About this time he entered into an agreement with James Davie, an Edinburgh friend, to manufacture sal ammoniac from soot, by a method they had jointly discovered before Hutton had left Edinburgh. This undertaking operated successfully for many years and no doubt added to Hutton's income.

Hutton returned to Edinburgh in the summer of 1750. He decided against practicing medicine and chose instead to take up farming as an occupation on the small farm he had inherited from his father at Slighshouses, Berwickshire, forty miles southeast of Edinburgh. Hutton recorded that he became interested in farming some years previoulsly after reading Jethro Tull's well-known book *Horse-Hoeing Husbandry*. The standard of farming in Scotland at that time was low and because Hutton investigated thoroughly any subject in which he became interested, before settling at Slighshouses he spent about a year (1752-1753) on a farm at Belton, near Yarmouth, in East Anglia, an area in which good farming practice prevailed. While there he made many journeys on foot into other parts of England to study agriculture and he acquired the habit of examining rock outcrops. It was in 1753, according to Playfair, that Hutton first began to study geology. As a student of farming he must have observed that in England soils vary markedly from place to place, and this may have stimulated an interest in the subject.

In 1754 Hutton spent some months traveling in Holland, Belgium, and northern France to improve further his knowledge of agriculture, and again he took the opportunity to add to his knowledge of geology. At the end of that year he moved to Slighshouses, where he spent the next fourteen years farming his land in a more scientific manner than had hitherto been customary in Scotland. So far as is known this period of his life was uneventful, except that he made a journey to northern Scotland in 1764 with his close friend George Clerk of Penicuik[2] chiefly to study geology, to which, according to Playfair, Hutton was then giving much attention. Slighshouses was an isolated farmhouse and Hutton must have lacked congenial company, although one friend, Sir John Hall of Dunglass, a man interested in both farming and science, lived in the neighborhood. The future course of Hutton's life suggests that he may have spent much time reading scientific literature, for his interests were never confined solely to geology.

In 1767 Hutton, in association with Clerk and Hall, became a member of the committee of management of a projected canal to join the Forth and Clyde rivers. He continued to take an active part in the work of the committee for some twenty years.

About 1768, after bringing his farm into good condition, Hutton was able to let it. He then moved to Edinburgh, where he spent the rest of his life, living with his unmarried sisters. There was in Edinburgh at that time a Philosophical Society (later incorporated as the Royal Society of Edinburgh). Hutton became a member and read several papers to the society, only one of which was published. Playfair states that in Edinburgh much of Hutton's time was occupied with experimental chemistry; but he published nothing on the subject until late in his career. A visitor to his apartment in 1772 recorded that "his study is so full of fossils and chemical apparatus that there is hardly room to sit down."

Hutton was by temperament both sociable and hospitable and he entered fully into the intellectual and social life of the city. Joseph Black became his most intimate friend. Others of about his own age with whom he associated closely were Adam Smith, James Lind (1736–1812), Adam Ferguson, James Burnett (Lord Monboddo), John Hope, and John Walker. Through Black he became a friend of James Watt, in whose work he took much interest. About 1781 he first met Playfair,[3] and later he befriended Sir James Hall, who attained distinction as a geologist and chemist.

In 1774 Hutton made another tour into England and Wales. He visited Birmingham and with Watt examined the salt mines in Cheshire. In an unpublished letter to George Clerk he reported that he had been studying both geology and agricultural practice during this tour; and he implied that he was now familiar with the geology of England, with the exception of Cornwall. He later obtained a report on the geology of Cornwall from Watt's son, Gregory. During Hutton's tour the elder Watt probably introduced him to some members of the Birmingham discussion group later known as the Lunar Society, for he afterward corresponded with Erasmus Darwin and Mathew Boulton.

In 1777 Hutton published in Edinburgh a small pamphlet entitled *Considerations on the Nature, Quality, and Distinctions of Coal and Culm*. Its purpose, commercial rather than geological, was to establish the claim that the low-grade stony coal (culm) then exported from Edinburgh for lime burning should qualify for a lower rate of duty. This pamphlet, and Hutton's association with the Forth and Clyde canal, suggest that the practical value of his geological knowledge was already recognized.

When the Royal Society of Edinburgh was founded in 1783, Hutton became one of its most active supporters, believing that the establishment of the Society was important for the progress of science. His active interest in geology continued and from 1785 to 1788 he visited several parts of Scotland, the Isle of Man, and England to extend his knowledge. In 1788 Hutton was elected foreign member of the French Royal Society of Agriculture. It is possibly significant that the president of the society at that time was Nicholas Desmarest.

After 1788, so far as is known, Hutton made no more field excursions; and from 1791 he was subject to recurrent illness.[4] He spent these years preparing his lesser known works on chemistry, physics, and philosophy for publication. In 1795 he published the definitive two-volume edition of his *Theory of the Earth*. His friends had previously urged him to publish this work, and he was finally prompted to do so to counter Richard Kirwan's strong criticism of the theory.[5] Finally, Hutton began the preparation of another work, the "Principles of Agriculture," but his death prevented its publication.

The variety of subjects that Hutton studied intensively, and his general way of life, indicate that he was a man interested in knowledge for its own sake, without thought of personal advancement, and his works show an overriding intent to fit all the subjects he discussed into the framework of his deistic philosophy.

The illness that led to Hutton's death was stated by Black to have been caused by stones in the bladder. The first attack in 1791 was cured by a severe operation, but a recurrence set in during 1794. Thereafter he was confined to his house, although he remained cheerful, mentally alert, and able to read and write between bouts of severe pain.

Hutton never married; he was survived by one unmarried sister, Isabella, and a natural son, James, probably born about 1747, when Hutton was still a student. His son, employed for many years in the General Post Office in London, married and raised a family. Hutton kept in contact with him, providing money when he was in need. After Hutton died, Isabella Hutton presented his geological specimens to Black, who, in turn, gave them to the Royal Society of Edinburgh, on conditions which should have ensured that they would be properly cataloged and preserved. A few years later they were transferred to the university museum, then curated by Robert Jameson. They were exhibited for a time, but ultimately disappeared and no trace of them has since been found.

Geology. Hutton's most important contribution to science was his theory of the earth, first announced in 1785. Hutton had then been actively interested in geology for fully thirty years. It is known that he had completed the theory in outline some years earlier, and according to Black, writing in 1787,[6] Hutton had formed its principal parts more than twenty years before. In essence the theory was simple, yet it was of such fundamental importance that Hutton has been called the founder of modern geology. Much has been written about the scientific and intellectual background in eighteenth-century Europe at the time Hutton formed his theory, but its novelty can only be appreciated when related to the existing state of geological knowledge.

Interest in various branches of the earth sciences was then widespread, but recognition of geology as an individual science had scarcely begun. The mining of economic minerals was one of the oldest industries, but the development of scientific mineralogy was retarded by the undeveloped state of chemistry and crystallography. Nevertheless, through mining and quarrying operations, a knowledge of stratigraphy must have been acquired locally, but it remained rudimentary because of the almost universal belief that the fossiliferous sediments had been deposited by, or during the retreat of, the Noachian flood. While fossils themselves had long aroused interest (it was recognized that some forms could not be matched by known living species) their value as chronological and stratigraphic indexes had not yet been recognized except, perhaps, over very limited local stratigraphic ranges.

Crystalline rocks such as granite and gneiss, usually found in the core of mountain ranges, were regarded as primeval in age, and the sediments, often fossiliferous, on the flanks of the mountains and in low ground were assumed to be flood deposits. This classification carried no implication that any rocks were older than the five or six thousand years allowed for in biblical chronology. By about the middle of the eighteenth century, however, one or two authors had suggested that geological time might be longer than this chronology allowed. The effects of erosion, long recognized, formed a subject for debate over whether denudation would ultimately render the earth uninhabitable, or whether it would be compensated by the elevation of new lands on which life would continue.

There existed one major gap in geological knowledge. It was unsuspected that rocks of the type now classed as igneous formed a major and widely distributed rock group, wholly distinct in origin from the sediments. The extrusion of lava from active volcanoes was looked on as a local and superficial phenomenon. After about 1740, Italian and French naturalists recognized the existence, locally, of volcanic cones and lava flows in areas where there was no record of volcanic activity in historic times; but many years passed before it was realized that volcanic activity had been worldwide, not only in historic times but in past geologic ages. The igneous origin of many rocks interbedded in, or otherwise closely associated with, the sediments was still unrecognized.

Broadly speaking, the position was that many geological observations had been made and recorded in the literature; but previous attempts to synthesize these observations into a general "theory of the earth" were unscientific and had not proved acceptable. The issue had been confused and progress retarded by a literal belief in the biblical account of creation and the universal flood.

The Theory of the Earth . Hutton's theory, or "System of the Earth," as he called it originally, was first made public at two meetings of the Royal Society of Edinburgh, early in 1785. The society published it in full in 1788, but offprints of this paper were in circulation in 1787, and possibly in 1786. The theory first appeared in print in condensed form, in a thirty-page pamphlet entitled *Abstract of a Dissertation... Concerning the System of the Earth, Its Duration, and Stability*, which Hutton circulated privately in 1785. The interest of this pamphlet is that it states all the conclusions which were essential to the theory as a whole. It emphasizes that even at this early date Hutton's thinking was far ahead of that of his contemporaries. For this reason, and because it is more easily comprehended than the full version, it is summarized here.

Hutton's approach in the *Abstract* is logical, but his thought is not translated into clear and incisive prose. As with almost all that he wrote (other than private letters), his style is prolix and abstruse, so that the text must be read with care to appreciate its full significance.

Hutton describes briefly his purpose in carrying out the inquiry, the methods he employed in reaching his conclusions, and the conclusions themselves. His purpose was to ascertain (*a*) the length of time the earth had existed as a "habitable world"; (*b*) the changes it had undergone in the past; and (*c*) whether any end to the present state of affairs could be foreseen. He stated that the facts of the history of the earth were to be found in "natural history," not in human records, and he ignored the biblical account of creation as a source of scientific information (a view he expressed explicitly later on). The method he employed in carrying out his inquiry had been a careful examination of the rocks of the earth's crust, and a study of the natural processes that operated on the earth's surface, or might be supposed, from his examination of the rocks, to have operated in the past. In this way, "from principles of natural philosophy," he attempted to arrive at some knowledge of the order and system in the economy of the globe, and to form a rational opinion as to the course of nature and the possible course of natural events in the future.

Hutton concluded that rocks in general (clearly he referred here to the sedimentary rocks) are composed of the products of the sea (fossils) and of other materials similar to those found on the seashore (the products of erosion). Hence they could not have formed part of the original crust of the earth, but were formed by a "second cause" and had originally been deposited at the bottom of the ocean. This reasoning, he stated, implies that while the present land was forming there must have existed a former land on which organic life existed, that this former land had been subjected to processes of erosion similar to those operating today, and that the sea was then inhabited by marine animals. He then concluded that because the greater part of the present land had been produced in this way, two further processes had been necessary to convert it into a permanent body resistant to the operations of water: the consolidation of the loose incoherent matter at the sea bottom, and the elevation of the consolidated matter to the position it now occupies.

Hutton then considered two possible methods of consolidation. The first, deposition from solution, he rejected because the materials of which ordinary sediments are composed are, with few exceptions, insoluble in water. He adopted the alternative, fusion of the sediments by the great heat which he believed to exist beneath the lower regions of the earth's Crust. Heat, he claimed, was capable of fusing all the substances found in different types of sediment.

He also concluded that the extreme heat that fused the sediments must be capable of "Producing an expansive force, sufficient for elevating the land from the bottom of the ocean to the place it now occupies." He supported this conclusion by stating that the strata formerly deposited in regular succession at the bottom of the ocean are now often found broken, folded, and contorted, a condition to be expected as a result of the violently expansive action of subterraneous heat.

Hutton then discussed the direct evidence of the action of heat, which he had found in the rocks themselves. He mentioned mineral veins containing matter foreign to the strata they traverse, the widespread occurrence of volcanoes, and the occurrence of what he called "subterraneous lavas." (The examples quoted here, and in the fuller version of the theory, indicate clearly that he was referring to what are now known as igneous intrusions.)

Hutton next claimed that his theory could be extended to all parts of the world, a generalization that was by then justified because similar rocks occur in other countries. He also claimed that the theory, based on rational deductions from observed facts, was not "visionary."

Finally, Hutton discussed one of the principal objects of his inquiry, the length of time the earth had existed as a habitable world, that is, in effect, the question of geological time. He rejected as humanly impracticable the possibility of estimating geological time by measuring the rate at which erosion is wearing down the land. Hence he concluded

... That it had required an indefinite space of time to have produced the land which now appears;... That an equal space had been employed upon the construction of that former land from whence the materials of the present came;... That there is presently laying at the bottom of the ocean foundation of a future land, which is to appear after an indefinite space of time..... so that, with respect to human observation, this world has neither a beginning nor an end [pp. 27-28].

Hutton was not prepared to be more definite than the facts allowed.

It was also in the *Abstract* that Hutton disclosed for the first time his philosophic belief that there exists in nature evidence of wisdom and design. He believed that the natural processes operating on an within the earth's crust had been so contrived as to provide for the indefinite continuance of the earth as a habitable world, providing means for the continuing existence of living beings, and that his theory provided support for this conclusion. The final paragraph of the *Abstract* includes the following statement: "Thus, either in supposing Nature wise and good, an argument is formed in confirmation of the theory, or, in supposing the theory to be just, an argument may be established for wisdom and benevolence to be perceived in nature." Hutton's theory ran counter to the belief then widely held that the present world was created by a divine being, fully populated by animal and plant life, at a time that could be measured by human records.

Hutton makes few references in the *Abstract* to the evidence on which he bases his theory. This is discussed in detail in his 1788 paper. Here, in discussing geological time, the conclusion he draws from fossils is of particular interest. He states:

Time...is to nature endless and as nothing.... The Mosaic history places this beginning of man at no great distance; and there has not been found, in natural history, any document by which a high antiquity might be attributed to the human race. But this is not the case with regard to the inferior species of animals... We find in natural history monuments [that is, fossils] which prove that those animals had long existed; and we thus procure a measure for the computation of a period of time extremely remote, though far from being precisely ascertained [pp. 215, 217].

From 1785 onward Hutton continued to collect new information to support his theory, which he published later in a two-volume work, *Theory of the Earth: With proofs and Illustrations; in Four Parts*(1795). In this edition the 1788 theory is restated with no essential change in the first chapter of volume I. The remainder of the two volumes deals principally with the supporting proofs and illustrations. Only two of the four parts promised on the title page were published in 1795. Hutton left an unfinished manuscript containing six chapters totaling 267 pages, evidently intended for inclusion in an additional volume of the *Theory*. These chapters, published as volume III in 1899, are of considerable interest, for they contain accounts of several of his later geological journeys. A study of the three volumes reveals the remarkable extent of Hutton's geological knowledge, the thoroughness of his investigations, and the acuteness of his observations.

The methods Hutton had employed in forming his theory were essentially the same as those employed by modern field geologists. He examined many different types of rocks, paying attention to their structural relations one to another; and he considered in detail the mineralogical and chemical composition of individual rocks. He also studied intensively the physical processes now operating on the earth's surface. In addition he examined British, European, and American literature to find support for his conclusions.

The method he employed in formulating his theory was, as he claimed, based on the principles of natural philosophy. Some of his conclusions can be described as speculative, and others were based on misinterpreted evidence, but these elements in the theory do not destroy its validity as a whole. It could be argued that Hutton's theory incorporated ideas that he had gained from other authors. This question is difficult to answer, for although he had read extensively, he seldom if ever quotes the work of another author in a manner that suggests he had made use of his ideas. More often, references are made either to correct a particular author, or to confirm Hutton's own conclusions. His originality lies in the use he made of facts and ideas, not in their sources.

The most important advance in geological science embodied in Hutton's theory was his demonstration that the process of sedimentation is cyclical in operation, a principle now accepts as axiomatic. Hutton's cyale involved the gradual degradation of the land surface by erosion; the transport of eroded matter to the sea, there to be deposited as sediments; and the consolidation of the sediments on the sea bottom, followed by their elevation to form new land surfaces, which in turn were subject to erosion. Hutton showed that this cyclic process must have been repeated an indeterminate number of times in the past, and because he could find no evidence to suggest that it might cease, he assumed that it would continue indefinitely.

In constructing his theory Hutton had used as a working hypotheses the assumption, based on his own observations, that the geological evidence provided by surface rocks provided both a key to the past and an indication of the probable future course of events. His theory formulated for the first time the general principle that some fifty years later came to be known as uniformitarianism.

In the fields of physical geology and gemorphology Hutton's views were strikingly modern. His knowledge of the processes of erosion and the agents that activate these processes, particularly river action, was through. His imaginative reasoning led to one remarkable conclusion about the possible action of glaciers in Switzerland. He had read in H. B. de Saussure's *Voyages dans les Alpes* (Neuchatel, 1779) a description of scattered boulders of granite, often of immense size, which rested on limestone in the Saleve area, and had obviously been transported there from a distant source. De Saussure believed that their presence could not be accounted for by river action, and he suggested that they had been brought there by a vast debacle or general flood. Although he had not visited Switzerland, Hutton proposed a solution much nearer the truth. He suggested that in the past, when the height of the Alps had been very much greater. "immense valleys of ice sliding down in all directions towards the lower country, and carrying large blocks of granite to a great distance" (*Theory*, II [1795], 218), had transported these erratic blocks; and that in the course of time the upper parts of the mountains that had carried these glaciers had been removed by erosion. The true explanation, that the distribution of erratics of this sort had been effected by great ice sheets covening much of Europe, was not put forward until some forty years later.

Hutton also made contributions, second only in importance to his main theory, in the field of igneous geology. He was much impressed by the worldwide distribution of volcanic activity, and by the new discoveries that in some areas there occurred lavas that must have been erupted in prehistoric times. He made a detailed study of the numerous outcrops of igneous rocks in or near Edinburgh (some almost on his own doorstep), and of others in various parts of Scotland. He distinguished two types, lavas and intrusions, including among the latter both flat sheets and dyes, and he established for the first time the existence of a new class of rocks, the intrusive igneous rocks. He concluded that all igneous rocks originated in what he called the "mineral region," a subcrustal zone of undefined depth in which heat of sufficient intensity to melt rocks prevailed.

Hutton also established the igneous origin of granite, a rock hitherto classed as primeval and believed by geologists of the Wernerian school to have been deposited from water. His study of granite affords an instructive example of Hutton's acute powers of observation and reasoning and the fact that, in general, he did not reach conclusions without sound evidence to support them.

In his 1788 paper he mentioned that some of the rocks of the earth's crust are not stratified, in particular granite. He reserved judgment on the question of the origin of granite but claimed that if one species of granite could be shown to have existed in a state of fusion, then this conclusion could be extended to other varieties of the same rock. He described a particular, and quite abnormal, type of granite from Portsoy, in northeast Scotland, a specimen of which had been sent to him. He had not seen the outcrop but had been informed that it graded into granite of normal type.

This specimen (see Figure 1), illustrated in his 1788 paper, is clearly an example of the variety known as graphic granite, owing to a superficial resemblance to oriental writing evident when the rock is broken in a particular direction, perpendicular to the long axis of the contained quartz crystals which are embedded in a groundmass of feldspar. The Quartz crystals then appear skeletal in form, with reentrant angles. Hutton concluded "it is not possible to conceive any other way in which these two substances, quartz and feld-spar, could thus be concreted, except by congelation [cooling] from a fluid state, in which they had been mixed" ("Theory" [1788], p. 256). That is to say the rock had cooled from a fused melt. This was a sound conclusion, for there is nothing in the appearance of the rock to suggest a sedimentary origin.

In a later paper, read to the Royal Society of Edinburgh in 1790, Hutton indicated that he had previously reserved judgment on the granite question as a whole, because he had not then decided whether granite.

... was to be considered as a body which had been originally stratified by the collection of different [that is, sedimentary] materials, and afterwards consolidated by the fusion of these materials; or whether it were not rather a body transfused from the subterraneous regions, and made to break and invade the strata in the manner of our whinstone or trapp ["Observations on Granite," in *Transactions of the Royal Society of Edinburgh*, **3** (1794), 77–78].

Hutton knew of the existence of foliated granite gneisses in Scotland, and he had read that such rocks were known to de Saussure in Switzerland, who had distinguished them from massive unfoliated granite. Hutton therefore suspended judgment until he had examined the margin of an outcrop of massive granite. This he did in the autumn of 1785 when visiting the duke of Atholl's estate at Glen Tilt, Perthshire. There Hutton found "the most perfect evidence, that granite had been made to break the Alpine strata, and invade that country in a fluid state. This corresponded perfectly with the conclusion which I had drawn from the singular specimen of the Portsoy granite" (*ibid*., 79–80). Hutton made journeys into other parts of Scotland where he obtained further confirmation of his conclusion. The school of geologists who accepted Hutton's ideas about the origin of igneous rocks came to be known as "plutonist," a name first used by Kirwan.

While the thoroughness of Hutton's investigations and the ingenuity of his arguments are evident, some of his deductions and conclusions were unjustified. This was especially true in his discussions of the causes that he suggested were responsible for the consolidation and elevation of the strata. Here he was breaking new ground and attempting to solve problems that for the most part were insoluble at that time. He must have realized that is his theory was to be accepted, these problems could not be ignored. The solutions he reached were unduly influenced by the powers he attributed to the hot "mineral region" that he believed existed below both the continents and the oceans, powers for which he could produce little convincing evidence, although a source of heat was certainly present.

In discussing consolidation, although he did not consider seriously the possibility that compaction might have resulted from the pressure exerted by a thick mass of sediments, he did suggest that pressure could have driven the water out of porous rocks. Some of the rocks with which he was familiar, particularly the dynamically metamorphosed sediments in the Scottish Highlands and some unmetamorphosed limestones, were crystalline. This knowledge appears to have influenced him in reaching the conclusion that consolidation had been effected by heat. He claimed that many, although not all, the sediments had actually been fused. A difficulty inherent in this argument was that heat of the intensity he envisaged would have decomposed limestones. He dealt with this problem in the following statement:

The essential difference, however, between the natural heat of the mineral regions, and that which we excite upon the surface of the earth, consists in this; that nature applies heat under circumstances which we are not able to imitate, that is, under such compression as shall prevent the decomposition of the constituent substances, by the separation of the more volatile from the more fixed parts [*Theory*, I (1795), 140].

Sir James Hall was later to prove experimentally that this assumption was justified.

The problem raised by Hutton's demonstration that consolidated strata had been elevated to form dry land was a formidable one. He might perhaps have evaded the issue, as others had done, by suggesting that elevation had resulted from the operation of some cataclysmic action comparable in kind to that which brought about earthquakes. Had he done so, his theory might have received less criticism, but that was not Hutton's way. He wished to get to the root of the matter. He was clearly impressed by the immense force exerted by volcanic activity, in breaking through great thickness of consolidated strata, followed by the eruption of lava with explosive violence; and, as he indicated in the *Abstract*, he supposed that the shattering and distortion of strata that once existed as undisturbed horizontal beds must have resulted from the action of the same force. He was also familiar with all the properties of heat known at that time, including its expansive effects on solids, liquids, and gases. He inferred, correctly, that there must exist in his "mineral region" a potential source of immense power (now it would be termed energy), and he assumed that it was heat that brought this power into action. He therefore concluded "that the land on which we now dwell has been elevated from a lower situation by the same agent employed in consolidating the strata... this agent is matter actuated by extreme heat, and expanded with amazing force" ("Theory" [1788], p. 266). He made no attempt to explain matters in more detail, but he qualified his conclusion by adding, "The raising up of a continent of land from the bottom of the sea is an idea that is too great to be conceived easily in all parts of its operation, many of which are perhaps unknown to us" (*ibid*., p. 295). That Hutton failed to solve this problem, one that continues to engage the attention of geologists, is not surprising, but at least he attempted to solve it scientifically.

Reception of the Theory . It has often been stated that Hutton's theory was little understood before the publication in 1802 of Playfair's *Illustrations of the Huttonian Theory of the Earth*. This may be true, and certainly Lyell seems to have derived his knowledge of Hutton's views principally from this source.[7] Neverthless the theory had been widely read before then, for it had already received critical notices in both British and foreign publications; translations of the *Abstract* and 1788 "Theory" had appeared in Germany[8] and France; and the theory had received some notice at least as early as 1805 in the United States. Undoubtedly Hutton's views became quite widely known in the early years of the nineteenth century. Yet in spite of the growing interest in geology, and the rapid accumulation of factual observations, it was not until after 1830 that his theories began to gain general acceptance, largely because of Playfair's *Illustrations* and the publication of Lyell's *Principles of Geology* (London, 1830-1833). Lyell accepted most, although not all, of Huton's views, and expounded them fully in his book; but he and his followers did not accept Hutton's conclusions on the importance of the erosional action of rivers. Some thirty years passed before geologists in both Great Britain and the United States realized that Hutton had been right.

The delay in the recognition of Hutton's work can be attributed to a variety of causes acting collectively: the natural conservatism of many geologists; reluctance to abandon belief in the biblical account of creation; the widespread influence of geologists of the Wernerian school; and the rise of catastrophism. By 1830, however, geologists, although still conservative in outlook, were much better equipped to assess the value of the Huttonian theory.

Agriculture and Evolution . Hutton must have retained an interest in agriculture long after he ceased farming, for shortly before he died he was engaged in preparing for publication a treatise entitled "Principles of Agriculture." This has survived as a manuscript of 1045 pages. Hutton stated in the preface that his objectives in writing this treatise were to assist the farming community to judge whether they were farming on sound scientific and economic principles; to promote the general good of the country; and for his own "pleasure in what has been in a manner the study of my life."

The treatise, based partly on Hutton's own experience and partly on the practice of the most successful husbandmen of his time, covers all branches of farming and animal husbandry, including implements and economics, and where appropriate, Hutton applied his scientific knowledge.

The most noteworthy part of the treatise appears in a section dealing with animal husbandry. Here Hutton outlined a theory of evolution. The question he raised was "how those varieties, which we find in every species, are procured; whether by simple propagation from original models, which had been created with the species, or whether from certain laws of variation, in the process of propagation of each species by the influence of physical causes" (p. 735). Using the dog as his example of a "species," Hutton found it "almost inconceivable" that the numerous different types of dog, "so wisely adapted to various different purposes,... should have arisen from the influence of external causes alone" (p. 736), unless "some intended principle in the original constitution of the animal" had operated. He then argued that without this factor, if several varieties or species of dog had existed originally, promiscuous interbreeding would have resulted ultimately in the production of a variety of dog with indefinite characteristics, a "compound species" or mongrel, and all the original varieties would probably have been lost; and we should never have seen "that beautiful illustration of design" exemplified in the different types of dog.

Hutton therefore suggested that originally the "species" had existed in only one form, and there was inherent in the constitution of the animal "a general law or rule of seminal variation" which would bring about constant changes in the animal, to a greater or lesser extent, "by the influence of external causes." Thus we should find varieties in the species "propagating for a long course of time under the influence of different circumstances, or in different situations; and we should in this see a beautiful contrivance for preserving the perfection of the animal form, in the variety of the species... . To see this beautiful system of animal life (which is also applicable to vegetables)" (pp. 738-739), Hutton wrote, we must consider that

... in the indefinite variation of the breed the form best adapted to the exercise of those instinctive arts, by which the species is to live, will be most certainly continued in the propagation of this animal, and will be always tending more and more to perfect itself by the natural variation which is continually taking place. Thus, for example, where dogs are to live by the swiftness of their feet and the sharpness of their sight, the form best adapted to that end will be the most certain of remaining, while the forms that are least adapted to this manner of the chace will be the first to perish [p. 739].

Hutton's conclusion that there is some inherent mechanism in "species," such as seminal variation, which could lead to the establishment of animal varieties may possibly have been suggested to him by his knowledge of the animal breeding experiments carried out by the eighteenth-century agriculturist Robert Bakewell, to whom he refers elsewhere in this section of the "Principles."

Physical Sciences. Hutton's interest in the physical sciences, particularly chemistry, physics, and meteorology, extended over many years, during which he kept himself informed of their progress. Toward the end of his life he published a three-part book entitled *Dissertations on... Natural Philosophy*, which is of considerable interest to the historian of science. The conclusions he reached in this work were often original and sometimes supported by experiments he had carried out himself. The principal subjects discussed are meteorology, phlogiston, and the theory of matter.

Part 1 contains four dissertations on meteorology, of which three, dealing with Hutton's theory of rain and his answer to DeLuc's critcism theory of the theory, had been previously published by the Royal Society of Edinburgh (1788, 1790). The fourth contains a discussion on winds. Hutton attributed the origin of rain to a mixture of air currents of different temperatures, saturated or nearly saturated with moisture. His theory attracted attention for some years, including a favorable comment from John Dalton as late as 1819, although J. D. Leslie had already shown it to fail on qualitative grounds in 1813.

Part 2 is entitled a "Chymical Dissertation Concerning Phlogiston, or the Principle of Fire," a subject evidently of particular interest to Hutton. It had been the topic of a paper he read to the Royal Society of Edinburgh in 1788, following an address by Sir James Hall on Lavoisier's new chemical ideas, to which Hall had been converted after visiting Lavoisier in Paris. These papers and the accompanying discussion occupied five meetings, but they were not published.

Hutton accepted the major advances made by Lavoisier, but took the view that the concept of phlogiston had been too hastily rejected. He did not accept Lavoisier's concept of *calorique*; in fact he strongly opposed it. His view was that heat, light, and electricity were all modifications of what he called "solar substance." Hutton also considered phlogiston to be some form of the solar substance, a principle of inflammability, without gravity, which could be transferred from one substance to another. He claimed that phlogiston was actually formed by vegetative matter and decomposed during the processes of breathing and burning.

Thomas Thomson, when discussing Hutton's views on phlogiston, described him as "a man of undoubted genius," but stated also that his views were set out in a "manner so peculiar, that it is scarecely more difficult to procure the secrets of science from Nature herself, than to dig them from the writing of this philospher," [9] Fortunately Hutton's conception of the nature and function of phlogistion has been discussed by J. A. Partington and D. McKie in sufficient detail to meet the needs of most readers.

Part 3 of the *Dissertations on... Natural Philososphy*, entitled "Physical Dissertations on the Powers of Matter, and Appearances of Bodies," constitutes more than half the book and contains Hutton's theory of matter. Briefly summarized, this theory suggests that to describe a body as made of small particles does not explain its nature, because if we suppose these particles to possess magnitude, we do no more than say large bodies are made of smaller bodies. Therefore the elements of a body must be something unextended. To these elements he gave the name "matter," reserving the name "body" to combinations of matter subject to powers of forces acting in various directions. He uses this conception to explain the various physical properties of bodies. Playfair emphasized the close affinity of Hutton's theory to that of Boŝcović, but he states specifically there was no reason to suppose Hutton had derived his conclusions from the latter. According to Playfair, Boŝcović's theory was hardly known in Scotland before 1770, whereas the earliest sketches of Hutton's theory were of much earlier date.[10]

Hutton continued his discussion of phlogiston in his last book, *Philosophy of Light, Heat*, and *Fire* (1794). Here he also raised the question whether there might be a species of light capable of producing heat in bodies without affecting the sense of sight. This idea, he stated, had been suggested to him by his own experience, he hoped to test it accurately when suitable apparatus could be constructed. He proposed the use of either a prism or colored glass to produce both red and blue light, but the only experiment he actually carried out was a crude one. He adjusted the position of two source of light, a coal fire for red light, and a flame for "compound" or white light, so, that each sources just permitted him to read, and he found that the amount of heat given off by the fire was much greater than that from the flame. He suggested, by analogy, that invisible light should exist, which would form a source of heat greater than that produced by the visible range of the spectrum: A few years later, William Herschel investigated the subject move thoroughly, confirming Hutton's suggestion.

Hutton's last contribution to chemistry was a paper on the "Sulphurating of Metals," read to the Royal Society of Edinburgh by a friend on 9 May 1796. The subject is discussed in terms of Hutton's ideas about light, heat, and phlogiston, and a correction is made of a conclusion he had drawn *Light*, *Heat* and *Fire*.

Philosophy . In 1794 Hutton published a threevolume treatise on metaphysics and moral philosophy entitled *An Investigation of the Principles of Knowledge*. This work followed on or arose out of his studies of the physical sciences. It received little notice when it first appeared, but Playfair discussed it in some detail and suggested that if the work were abridged and the obscurities removed it would deserve more attention. It has received little if any notice since playfair's time. In the *Principles of Knowledge* Hutton acknowledged the existence of a God whom he defined as "the superintending mind... a Being with perfect knowledge and absolute wisdom." He considered nature as subordinate to God, and that the two terms were not synonymous, for God is infinite and unchangeable, but nature limited and changing. While he included the animal, vegetable, and mineral systems as part of nature's general design, the term "nature" properly meant the whole of that action from which, in necessarily inferring design, we learn the existence of a superintending being.

Although occasionally accused of impiety in his lifetime, Hutton was not an atheist, and may be described as a deist. In almost all that he wrote, not only on geology but on agriculture and physical subjects as well, he introduced his belief that in nature there is abundant evidence of benevolent wisdom and design. To Hutton the earth as a whole was "a machine constructed upon chemical as well as mechanical principles, by which its different parts are all adapted, in form, quality, and in quantity, to a certain end... an end from which we may perceive wisdom in contemplating the means employed" ("Theory" [1788], p.216). The earth, in Hutton's view, was evidently made for man, will be led "to acknowledge an order, not unworthy of Divine wisdom, in a subject which, in another view, has appeared as the work of chance, or absolute disorder and confusion" (*ibid*., P. 210).

Hutton's attitude toward the Christian religion was recorded in a brief (Unpublished) manuscript entitled 'Memorial Justifying the Present Theory of the Earth Form the Suspicion of Impiety," which was evidently written sometime between 1788 and 1795, in answer to criticisms of his theory. In it he made no attempt to compromise with the Church, as Buffon had done. His view was that the ancient Jewish writings on which the Christian religion was founded can be accepted only insofar as they record the history of man upon earth. He denied the literal truth of the Mosaic account of creation, whose only significance, he stated, was its record that God had made all things in a certain order; and he thought it absurd to suppose that the term "day" used in that account could mean anything other than an indefinite period of time.

Hutton maintained that it was not the duty of religion to provide a history of the natural operations that had taken place on the earth in the past; but that this was the function of man, using his intellect and applying the methods of natural philosophy. He regarded the objectives of revealed religion and natural philosophy as essentially different, and saw no reason why one should interfere with the other, provided their different purposes were kept separate.

NOTES

1. This account of Hutton's life is based almost entirely on John Playfair, "Biographical Account."

2. Hutton was friendly with several members of a prominent scottish family, the Clerks of Penicuik. His particular friend was George, second son of Sir John Clerk who had been vice-president of the Philosophical Society of Edinburgh. George Clerk was interested in mineralogy and accompanied Hutton on several of his geological excursions. On marriage to a Miss Maxwell he assumed the name of Clerk-Maxwell, and the physicist Clerk-Maxwell is his descendant. Other members of the Clerk family accompanied Hutton on later hours.

3. See Playfair, *op. cit.,* p. 74 n.

4. Playfair gives the date incorrectly as 1793.

5. See Kirwan, "Examination of the Supposed Igneous Origin of Stony Substances," in *Transactions of the Royal Irish Academy*, **5** (1793), 51-81.

6. In a letter to Princess Dashkow, then director of the Imperial Academy of Sciences, St. Petersburg, in which Black summarizes Hutton's theory; see W. Ramsay, *Life and Letters of Joseph Black, M.D*. (London, 1918), 117–125.

7. See *Life, Letters and Journals of Sir Charles Lyell*, II (London, 1881), 47–49.

8. Werner MSS at Freiberg, IX, has an abstract of the 1788 "Theory."

9. See "Chemistry, (i)" in *Supplement to the 3rd ed. Encyclopaedia Britannica* (Edinburgh, 1801), I, 287.

10. See Playfair, *op cit*., p. 78 n.; see also R. Olson, "The Reception of Boscovich's Ideas in Scotland," in *Isis*, **60** (1969), 91-103.

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