losophy considers that these activities studied by science all belong to the universe; they all appear to be universal in their application under the proper conditions; in each department of research, moreover, an underlying unity is discovered; each succeeding generation of mankind discovers additional evidence of the interdependence and interrelatedness of all; it is, therefore, perhaps permissible to infer that all are the manifestations of a still deeper underlying unity, more far-reaching even than Einstein's law concerning the convertibility of matter into energy; moreover, since no energy can rise above its source, the universe, as the origin of all these activities, even of the "highest qualities" such as intellection and altruism, may be inferred to comprehend, sympathize with and to appreciate to the full their origin, their gradual synthesis and their peculiar resultant attributes. In this connection it appears probable that inductive study will reveal noümena as the totality of phenomena. Nevertheless, the study of nature, as generally understood, will, by itself, be insufficient. The inner meaning of the "cosmos" can not be expected to come from any inference or hypothesis which excludes from its premises "the intelligence in which nature, as it were, gathers herself up."

The Observer perceives that universal progress has been unbroken and unfailing, and that man, or some similar organism, will penetrate to the inner meaning of "things." Merriam considers a related point in an interesting article in a recent number of *Scribner's* (1927) entitled "Are the Days of Creation Ended?" The conditions for man to occupy the dominant position appear to be that he shall think and act impersonally; that he shall employ the inductive method in the broader sense as mentioned above; that he preserve his "stable heritages" intact, and that he appreciate time in generous terms as an essential factor in universal progress. The knowledge that was Newton's and Darwin's is to be but a basement stone, as it were, to the mighty temple of knowledge whose peak is to pierce the clouds. The greatest intellect, or the mind of the seer, is but a base upon which greater and grander examples are to rise and rest in countless thousands.

SOME SCIENTIFIC INSTRUMENT MAKERS OF THE EIGHTEENTH CENTURY[1]

By ROBERT S. WHIPPLE

ALTHOUGH numerous references are found in early British manuscripts to instruments of an elementary kind, chiefly for the determination of time or position, there is little evidence that before the sixteenth century scientific instrument making as a craft had obtained a position of any importance in Great Britain. The demand for instruments to assist navigation became more insistent as new lands were discovered and the length of the voyages increased.

Gradually the professional scientific instrument maker came into existence, two of the more distinguished being Humphrey Cole, the maker of the astrolabe used by Sir Francis Drake, and Elias Allen, the maker of Oughtred's double horizontal dial. In a book by Oughtred, dated 1632, describing the double horizontal dial, it is stated that it is printed for Elias Allen, "Maker of these and all other Mathematical Instruments, and are to be sold at his Shop over against St. Clements Church without Temple-barr."

With the discovery of the telescope in 1608 and its development by Galileo in the following years a great impetus was given to the instrument-making industry. Although Gregory and Newton propounded the reflecting telescopes known by their names in 1663 and 1666, they were unable to find makers capable of developing their ideas. Newton made his own instruments, but it was not until about 1730 that John Short, of Edinburgh, succeeded in making a Gregorian telescope.

The latter half of the seventeenth century was a great period of scientific development. Experimental science, under its leaders Boyle, Hooke, Newton and others, created a demand for scientific instruments which could only be satisfied by skilled craftsmen. The work of Hooke and Leeuwenhoek did much to develop the microscope and to draw attention to the possibilities of the instrument. Fortunately an instrument made about 1670, and somewhat similar in its details to that described and illustrated in Hooke's "Micrographia" (1655), has been preserved, and by Mr. Court's courtesy is exhibited here this evening. The evidence is, I think, convincing that this instrument was made by Christopher Cocks, the well-known telescope maker, who lived in Long Acre, and of whose telescopes there are at least three in existence. It is known that in March, 1672, Cocks was ordered to make a four- or five-foot Newtonian reflecting telescope, but the instrument was not successful. About 1680 he was admitted a freeman of the Spectacle Makers' Company.

[1] Address given at the weekly evening meeting of the Royal Institution of Great Britain, Friday, May 23, 1930. Lord Rayleigh, Sc.D., F.R.S., manager and vice-president, in the chair.

Owing to the publication of the "Micrographia" with its description of Hooke's microscope, great interest was created in microscopical work, and a demand arose for microscopes. Owing to the high quality of the optical and mechanical work the English microscope won a high reputation.

The greatest of the English instrument makers who bridge the seventeenth and eighteenth centuries is undoubtedly John Marshall. Nothing is known of his early life, but part of a diary recently discovered in the British Museum by Mr. H. W. Robinson, by whose courtesy I am able to publish an extract, has thrown an interesting sidelight upon Marshall's career. The record covers five years of Hooke's life, 1688 to 1693, with the exception of some few months, and was thought to be the diary of James Petiver, an apothecary friend of Hooke. Mr. Robinson has been able to prove that it was written by Hooke. The following is an extract, December 14, 1688: "One John Marshall who told me he was Dunning apprentice & now worked at turning at the 3 keys in Ivy Lane came to shew me some microscopes of his own making he told me Mr. Boyle had bought such of him." He appears to have set up later at the sign of the Gun as a maker of spectacles and microscopes, and there is little doubt that the microscopes were of the Hooke type. By 1690 he had built up a large business and had introduced a new method of grinding lenses on brass tools. Marshall's double microscope was undoubtedly the greatest advance made in microscope construction for many years. The instrument was fitted with coarse and fine focusing adjustments, and for the first time the limb which carried the eyepiece, the object-glass and the object formed one complete system which could be inclined as one unit. All the features are retained in the modern instrument.

The first outstanding English instrument maker in the eighteenth century is undoubtedly Benjamin Martin, a man who, as far as is known, was not apprenticed to the trade. He was born at Worplesdon, Surrey, in 1704, and began life as a plowboy, later becoming a teacher of the "three Rs" at Guildford. He devoted his spare time to the study of mathematics. A legacy of £500 relieved him from the necessity of teaching and enabled him to travel and lecture. He appears to have assisted at the lectures given by Dr. J. T. Desaguliers, which were eagerly attended by the fashionable world and were illustrated by experiments. Horne, afterwards president of Magdalen College, Oxford, sarcastically remarked that Ben Martin "who having attended Dr. Desaguliers' fine raree gallantry show for some years in the capacity of a turnspit, has, it seems, taken it into his head to set up for a philosopher." This is a hit at Martin's literary efforts, because he proceeded to publish a large number of text-books dealing with a great range of subjects. When it is considered that Martin was a self-educated man, the extent and thoroughness of his knowledge as shown in his publications are remarkable. He appears to have lived some time at Chichester, where he kept a school, and also wrote several elementary text-books and pamphlets describing scientific instruments. There is little doubt that he commenced to make scientific instruments in Chichester, not improbably being asked by the readers of his books where it would be possible to obtain the instruments mentioned.

About 1750 he moved to London to a house in Fleet Street, three doors below Crane Court, where he became famous as a scientific instrument and spectacle maker at the sign of "Hadley's Quadrant and Visual Glasses." Martin was essentially a teacher, and continued to write after he had made his home in London. The books impress one with the care he takes to make every individual step in an explanation clear, and with the detailed drawings and references with which he explains the construction and use of an instrument. This is strikingly illustrated in his description of the various orreries he constructed. The orrery was almost the latest scientific novelty, and Martin appears to have been much impressed with the educational possibilities of the instrument. In his "Young Gentleman and Lady's Philosophy in a continued survey of the works of Nature and Art"—a book which had a great vogue—he uses planetaria to describe the difference between the Ptolemaic and Copernican systems, and the phenomena of eclipses, etc. He was evidently prepared to supply either form of planetarium to suit his customers' wishes. In one of his tracts published in 1771, "The Description and Use of an Orrery of a new Construction," he gives full details of the capabilities of the instrument, and also "the theory of calculation for the wheel-work of an orrery to the most extreme Degree of Accuracy." The prices of the instruments ranged from £12 12s. upwards, depending on the number of bodies demonstrated, and the accuracy of their movements, or as Martin himself states "proportional to the work." That Martin must have continued to lecture till late in life is shown by the fact that the apparatus made is adapted to show "all the Phænomena [*sic*] of the Transits of Mercury and Venus over the Face of the Sun such as I shewed in Public to Thousands on the late memorable instance of 1769."

In 1740 Martin published a useful text-book on optics, "A New and Compendious System of Optics," and in many other writings took immense trouble to explain optical systems and instruments. His microscopes and especially his cabinets containing two or three instruments of various types were much sought after and still remain as examples of first-class workmanship and ingenuity. There is little doubt that he invented the drum type of microscope which had a great vogue, and is still made in large numbers on the Continent. If the invention of the glass micrometer as applied to a microscope was not actually due to him he was undoubtedly one of the first to employ it. He was also one of the first to apply rack and pinion focusing adjustments to the compound microscope, and to fit inclining movements to the pillar carrying the stage and mirror.

It is a cause of wonder to me how Martin was able to produce such a large number of books. The Dictionary of National Biography mentions thirty-one, although some of them are only leaflets. Many of his books passed through several editions, and at least one was translated into French. They undoubtedly helped to popularize science and to create an interest in scientific instruments. Shortly before his death at the age of seventy-seven he took his son into partnership, and unaware of the state of his affairs was adjudged bankrupt. He thereupon attempted suicide, and the wound hastened his death. His valuable collection of fossils and curiosities was sold by public auction for a trifling sum—a tragic ending to a more than usually successful career.

George Adams, the elder, perhaps the greatest of English scientific instrument makers, was born about 1704. It is known that he was apprenticed in 1718, and that he was established in business on his own account at Tycho Brahe's Head in Fleet Street in 1735. It is also known that he was making instruments for the East India Company in 1735–36. He obtained a world-wide reputation as a maker of globes. In 1766 he published the first edition of his book "A Treatise describing and explaining the construction and use of new celestial and terrestrial globes." Dr. Samuel Johnson, the lexicographer, wrote the dedication to the King, and for so doing received a present of "very curious meteorological instruments of a new and ingenuous construction." The book had a great vogue, passing through thirty editions.

Adams was essentially a mechanic, and delighted in good workmanship. There can be little doubt, I think, that the microscope was his favorite instrument, and he developed several types of it. In 1746 he published his "Micrographia Illustrata: or The Knowledge of the Microscope explained in several New Inventions, etc." The preface to the "Micrographia Illustrata" emphasizes the religious side of Adams's character, and also shows that he must have had the artistic and poetic temperament highly developed.

The first edition contained an account of a "New Universal Microscope," which was made to an entirely original design, the object being, as Adams states, "to have a Microscope which would be Portable and Universal, that is to say, One Only Instrument, by which all Sorts of minute Objects might be observ'd." The microscope was provided with six single lenses of different foci with a common focusing screw. Adams remarked of this focusing screw that it "is to be turned as your hands and arms are resting on the table, which is a conveniency to be met with in no other Microscope." A second edition of the "Micrographia Illustrata" appeared in 1747, and a fourth in 1771. Despite exhaustive researches it has not been possible to find a copy of the third edition—if it were ever published.

The fourth edition commences with a description of the variable microscope, of which Adams was evidently very proud. He states that "We owe the construction of the Variable Microscope to the ingenuity and generosity of a noble person," and we know that the "noble person" was the Earl of Bute. By having a compound eye lens and by introducing an auxiliary lens placed some distance above the objective the definition was improved. Adams also introduced the method of screwing two or three objective lenses one on top of the other. By drawing up the eye-piece relative to the object glass the power of the combination could be altered—hence the name "variable." Adams, in common with Martin and other makers of the period, developed the solar microscope with the large mirror projecting out of the window, by means of which brilliant illumination could be obtained and magnified images of the object projected on to a screen.

Adams appears to have given a great deal of consideration to the method of measuring the magnification of microscopes, and illustrates in detail in the "Micrographia Illustrata" (Plate 14, fourth edition) various micrometers for this purpose, amongst others the micrometer he made in 1761 for the silver microscope of George III. This instrument originally formed part of the King's Collection, and is now in the Lewis Evans Collection. It has been described by Messrs. Clay and Court at some length.[2] Although the details of workmanship in this instrument are excellent, the instrument as a whole must be regarded as an ornament rather than a serious contribution to microscopy. Such is not the case with the earlier instrument made for the King when Prince of Wales, and known as the "Prince of Wales" microscope. It is particularly interesting as embodying the method of mounting a microscope on trunnions—perhaps, as Clay and Court remark, the first microscope so sup-

[2] R. S. Clay and T. H. Court, "Two Microscopes made by G. Adams for King George III," *Journ. R. Micr. Soc.*, 1926, pp. 268–273, and *Supplementary Note, Journ. R. Micr. Soc.*, 1927, p. 255.

ported. There are three stages, one of which is of great interest, having micrometers registering in two directions at right angles. The screws have 100 threads to the inch, and the scales on the heads are divided into 100 parts, so that the micrometers read to 1–1000 in. A second stage was intended to carry a frog for demonstrations on the circulation of the blood. It is a matter of general knowledge that King George III was keenly interested in scientific matters and wished that his family should be instructed in science. Dr. Demainbray commenced to teach the royal family in 1754, and appears to have used for this purpose the apparatus which formed the major part of what is known as the King George III Collection. The instruments in the collection were catalogued in a manuscript book which is still preserved in the Kew Observatory and also in a catalogue which is now in the Science Museum at South Kensington. The instruments were housed at the Kew Observatory until 1841, when they were transferred to King's College, London. In 1925 they were removed to the Science Museum at South Kensington, where the majority of them can be studied. The story of the collection was told in some detail in a paper before the Optical Convention of 1926.[3] The majority of the instruments intended for instructional purposes were made by George Adams, although few of them bear his name. Fortunately two books of instructions have been preserved, and it is by means of these that it is possible to state that most of the instruments were made by Adams.[4]

The instructions consist of two manuscript books about 19 in. by 13 in., with two small books about 12 in. by 9 in. The pages of the latter are of blue paper, on which are pasted white sheets on which the illustrations have been drawn. One book is entitled: "A Description of an apparatus for explaining the Principles of Mechanicks made for His Majesty King George the Third by George Adams, Mathematical Instrument Maker to His Majesty. In Fleet Street, London, 1762." The second book is entitled: "A Description of the Pneumatic Apparatus made by George Adams in Fleet Street, London, 1761." In the case of the "Mechanicks" the final sheets of drawings were in course of preparation, the outlines having been drawn, but the shading is incomplete and reference figures have not been inserted. It was evidently intended that the sheets of drawings should be bound as a book to accompany the instructions, and probably that the latter should be bound also when the drawings were completed, but these were never finished. In the case of the "Pneumatics," drawings on plates the same size as the manuscript (19 in. by 13 in.) were in course of preparation, and those that are finished are excellently drawn. In the case of both books it was no doubt intended to have the manuscripts bound—as they are now a series of loose leaves in rough covers—but this was never done. The two books containing the comparatively rough drawings appear to have been the center around which Adams built up the experimental courses. In the case of the "Mechanicks" a little mathematical work is also included, although the course is essentially experimental and based on Desaguliers' translation of the classical work of 's Gravesande, the distinguished professor of mathematics of Leyden.[5]

Adams apparently cut out many of the illustrations from Desaguliers' book, and added pencil or ink modifications to guide the workman. An example of a modification of this kind is found in an apparatus intended to demonstrate experiments on pendulums and the impact of bodies; it is generally known as "'s Gravesande table." The central illustration in Plate 25 of Desaguliers' book has been cut out and modified. The additions are shown by the cross hatching, but the parts removed have been carefully cut away before mounting. The finished instrument can be seen at South Kensington, and comparing the original design with that made by Adams, one has to admit that the latter is more graceful than the original. The workmanship of the whole of this piece of apparatus is excellent. Adams evidently considered the cost of making apparatus, because several modifications are introduced with a view to reducing labor. The drawing of a table is shortened in pencil, with the words "Too long" written against it, and there are small pencil sketches at the side showing alterations. A ring is made to take the place of a fairly elaborate handle, and a simple glass basin is used instead of a brass bowl.

There can, I think, be little doubt that, judging from the large number of sketches that are dimensional, they must have formed the actual drawings from which the apparatus was built. Not improbably the workman had made some of the instruments previously for other customers, so that he did not require detailed drawings. The work of making the instruments may have spread over a few years. In the

[3] R. S. Whipple, "An Old Catalogue, and What it Tells us of the Scientific Instruments and Curios Collected by Queen Charlotte and King George III," *Proc. of the Optical Convention*, part II, 1926.

[4] It is by the courtesy of the Delegacy of King's College and the Director of the Science Museum that I have been able to examine these books.

[5] "Mathematical Elements of Natural Philosophy, confirmed by Experiments: or an introduction to Sir Isaac Newton's Philosophy." Written in Latin by the late W. James 's Gravesande, LL.D., professor of mathematics at Leyden, and F.R.S. Translated into English by the late J. T. Desaguliers, LL.D., F.R.S., and published by his son, J. T. Desaguliers. Sixth edition, 1747.

case of one of the pneumatic instruments mention is made of apparatus previously supplied and now "in one of the cabinets of the Palace at Richmond."

All through both books references are made to various scientific authors; for example, when discussing the Archimedean screw five references are given.

One of the most interesting instruments shown in detail is the rotating speculum suggested by Searson as an artificial horizon. Full details of the construction are given, and a manuscript copy of Emmerson's paper in the *Philosophical Transactions,* 47: 352, is included with the manuscript papers of the collection. Adams commences the description of the instrument with a short introduction:

I recieved this invention from the late Sir Jacob Ackworth, first Commissioner of his late Majesties Royal Navy; soon after the inventor Mr. Searson was unfortunately lost on board His Majesties Ship the *Victory.*

Adams' mechanical ability shows itself in his instructions as to lubrication:

It is necessary to put a drop of sweet Oil into the concave Steel polished segment of a sphere, for if the speculum be whirled without Oil it does not spin much above ten or twelve minutes, with Oil it will spin generally 36 minutes.

Only two of the illustrations are actually signed by Adams, although there is little doubt that the various notes are in his writing. There is a short four-page manuscript slipped into one of the books, which is a sheet of instructions with regard to some details of an instrument. Adams presumably wrote his notes out in this manner, and they were afterwards transcribed in the elaborate copy-book writing of the instructions.

The fourth edition of the "Micrographia Illustrata" is dated 1771, and Adams died in 1773. He must have lived a full life as, judging by the large number of instruments that may be found bearing his name, and by the "Catalogue of Mathematical, Philosophical and Optical Instruments" published in the end of the "Micrographia Illustrata," he must have had a large and flourishing business.

He left it to a son—George (born in 1750)—who added greatly to the prestige of the firm. He was a cultured man, and a favorite at court. He wrote a large number of books, the majority of which passed through more than one edition. The most famous of his books was his "Essays on the Microscope," published in 1787. In the preface he states frankly that he had intended to confine himself to a republication of his father's work, the "Micrographia Illustrata," but that knowledge of the subject had increased so much since his father wrote, that he felt the book had to be rewritten. Discussing the natural history side of the subject he states that he has endeavored to correct some of the faults in arrangement, etc., "by arranging the subjects in systematic order, and by introducing the microscopic reader to the system of Linnaeus, as far as it relates to insects." Chapter I is an extremely interesting history of the microscope, as observed by one who lived close to many of the inventions. In it he mentions that he invented an improved form of the lucernal microscope in 1774. In Chapter III he mentions that "this microscope was originally thought of, and in fact executed by my father; I have, however, so improved and altered it, both in construction and form, as to render it altogether a different instrument." He also mentions that "the great demand I have had for them has fully repaid my pains and expenses [*sic*] in bringing it to its present state of perfection." The lucernal was a simple compact form of projection microscope which met with general approval as an instrument which could be conveniently demonstrated to a number of people at the same time.

A second and enlarged edition of the "Micrographia Illustrata" appeared in 1798, edited with great care by F. Kanmacher. This editor in a footnote dwells on the fact that Adams had not given full credit to Benjamin Martin for what he had done to develop the microscope. Adams's "Geometrical and Graphical Essays," first published in 1790, was an extremely useful text-book for surveyors, civilian and military. The lectures on "Natural and Experimental Philosophy," first published in 1794, in five volumes, very nearly cover the range of physics as then understood—or, in the words of the subtitle, "describing in a familiar and easy manner the principal phenomena of nature, and showing that they all cooperate in displaying the goodness, wisdom and power of God." One is much impressed with the immense amount of work involved in the preparation of these books, for they are all full of individuality. The lectures were evidently written under difficulties. In the preface the author mentions "During the composition of these Lectures I have had to attend to the grateful calls of daily business, and have struggled with much weakness and langour." He passed away on August 14, 1795. We learn from an editorial note to the second edition of the "Essays on the Microscope" that Adams at the time of his death was preparing a new edition and that he had other books in view. After his death his books and instruments were sold by auction, and the stock and copyright of his books were purchased by the brothers W. and S. Jones. William Jones was responsible for the editorial work and the republishing of several editions of Adams's books. The firm also continued to make instruments to the Adams design for many years.

The manuscripts and plates of Adams the elder were inherited by his widow, who gave them to her younger son Dudley. He edited a thirtieth edition of the "Treatise on the Globes," published in 1810. It is said that he had intended to publish another edition of the "Micrographia Illustrata," but it is not improbable that the revised edition (1798) of his brother's "Essays on the Microscope" rendered this unnecessary. Dudley Adams appears to have continued in the instrument business, as Mr. Court possesses a statement written on the back of a shop print, about 1800, of the wholesale trade terms for telescopes. These were evidently of the short brass draw-tube type which Dudley Adams had developed. The note attached to the price list states that "the object glasses not being single but achromatic" shows that non-achromatic glasses were sometimes sold.

Time has only allowed me to dwell in detail on four instrument makers in this century so full of scientific development. Their names are not so well known to the general public as those of Doliond, Herschel and Ramsden. Nevertheless the men whose work I have briefly described did an immense amount to popularize science and to raise the standard of scientific instrument craftsmanship. How world-wide this reputation for good work became is best seen by the number of instruments of English eighteenth century workmanship treasured in the Continental museums.

SCIENTIFIC EVENTS

THE INTERNATIONAL VETERINARY CONGRESS

THE International Veterinary Congress, which met in London during the first week in August, passed resolutions covering most of the subjects discussed on the previous days.

Delegates decided to accept the invitation of the American Veterinary Medical Association to hold the next congress in the United States in 1934, probably at Boston. Cheers greeted the announcement that the Budapest Prize, a gold medal, richly wrought, which was instituted when the congress met in that city, had been awarded to Professor Hutyra and Professor Marek, of Budapest, for the best work on veterinary science since the last congress. This consisted of a revised edition of a volume on the "Pathology of the Internal Diseases of Domesticated Animals." Professor Hutyra, who responded on behalf of himself and his colleague, is president of the permanent committee of the congress, rector of the Royal Hungarian Veterinary High School, and a member of the Upper House, Budapest.

Resolutions were carried with acclamation thanking the British Government and many individuals for their hospitality to delegates, and to Sir John McFadyean, of Leatherhead, for presiding. It was decided to increase the personnel of the permanent commission from 25 to 40.

In a resolution on foot-and-mouth disease, the congress urged that every country should determine the type of virus present in each outbreak. The most efficient disinfecting agents were moist heat and sunlight, and the chemical agents potassium, sodium hydrate and formalin. The value of passive immunity, according to the resolution, had been established, and its use in practice under favorable circumstances should be encouraged. It was desirable that all possible efforts should be made to discover an efficient method of active immunization.

The wide-spread occurrence of infectious abortion of cattle in all civilized countries led the congress to suggest an international scientific investigation within the purview of the International Bureau for Animal Diseases in Paris. The congress recommended the creation of a special section for meat and milk in the next congress. It also emphasized the necessity of state regulation for the control of the health of domestic animals, and for the title of veterinary surgeon to be protected by a recognized diploma.

The next resolution expressed the view that sufficient knowledge of practicable methods was now available to eradicate rinderpest within a reasonable period of time in any country which would provide adequate facilities for their application, and the congress urged all governments to cooperate to this end.

Resolutions were also carried concerning the teaching of zootechnics; the need for establishing in every country an organization similar to the German for combating diseases of the new-born animals, and the urgency for drawing up rules for the control and standardization of veterinary biological products.

INTRODUCTION INTO THE UNITED STATES OF PLANTS RESISTANT TO DISEASE

A STATEMENT given out by the U. S. Department of Agriculture states that two explorers of the department, H. L. Westover and K. A. Ryerson, are in North Africa looking for wilt-resistant alfalfas and fruits adapted to the United States. They will later continue their exploration in Spain.

Mr. Westover, a forage crop specialist, is now making preliminary surveys in the principal alfalfa-