the bulk of the world's new supply derived from the mines at Great Bear Lake and refined by the Eldorado Company at its Port Hope plant comes to the Council for test and certification.

Turning to another of many fields, I would like to mention the very important programme which has been initiated by the Committee on Aviation Medicine under the chairmanship of the late Sir Frederick Banting. It was on the business of this Committee that Sir Frederick was proceeding to England when he lost his life in a flying accident (see NATURE of May 3, p. 535).

All this great range of work of which I have been speaking is going forward in Canada in the closest sympathy and understanding both with the authorities in Great Britain and also with our mutual friends and colleagues in the United States. In order to help in the maintenance of effective contact the British Government has established a Scientific Liaison Office with the Council in Ottawa and we have been privileged to receive first Prof. R. H. Fowler and more recently Sir Lawrence Bragg.

At the present time a number of the senior members of the National Research Council are in England to familiarize themselves with the latest methods and requirements so that work in Canada may be kept related to problems of immediate practical importance.

There is a constant flow and interchange of workers and the various problems are taken up as available facilities best indicate. Needless to say, there is no delay or reservation in making the results available for application and use.

TERCENTENARY OF NEHEMIAH GREW (1641–1712)

By DR. AGNES ARBER

NEHEMIAH GREW will always be held in honour by botanists as the co-founder with Marcello Malpighi of the science of plant anatomy. It is true that in his ideas about plant cells he did not advance much beyond Robert Hooke, who, in 1665, figured and named these units; but, as regards knowledge of vascular structure, the position is very different. Grew and Malpighi not only initiated the study of the bundle system of the flowering plant, but also carried it to a surprisingly high level, considering that they had to start from the very foundations. Grew's first book, "The Anatomy of Vegetables Begun" (1672), contains the earliest printed illustration showing vascular bundles as seen in section under the microscope. He followed up this work in 1673 and 1675 by treatises on the detailed anatomy of roots and of stems. Finally he brought all his results together, in 1682, in a splendidly illustrated folio, "The Anatomy of Plants", which included improved second editions of his first three books, as well as much additional matter. The excellence of Grew's botanical morphology and anatomy has been recognized fully; indeed his reputation in this line is deservedly so great that it has tended to overshadow the other facets of his output. It seems worth while, therefore, in this, his tercentenary year, to direct attention to certain less specialized aspects of his scientific work.

Grew's general attitude towards biology cannot be understood unless one realizes how deeply he was committed to a mechanistic view of the universe. It seems likely that Hooke, and also Descartes, had to some extent turned his mind in this direction, though in the seventeenth century such ideas were so much in the air that it is scarcely necessary to look for specific sources. It was owing to the mechanistic viewpoint of that period, that the microscope, for example, was hailed as an instrument which was destined to clear away all inconvenient mysteries. Hooke hoped that by the help of glasses "we may perhaps be inabled to discern all the secret workings of Nature, almost in the same manner as we do those that are the productions of Art, and are manag'd by Wheels and Engines, and Springs, that were devised by humane *Wit*". Grew enlarges upon this analogy between the world and a man-made machine, and seems to find it entirely satisfying. He says that "all *Nature* is as one Great *Engine* made by and held in" the hand of God. He regards this engine as having been set in motion by the Great First Cause, to which all subsequent effects can be traced back; he considers that the original causation was all that was necessary, and that, in the normal course of events, no subsequent interference has occurred. "And as it is the watchmaker's *Art*," he says, "that the *Hand* moves regularly from hour to hour, although he put not his finger still to it: so it is the demonstration of *Divine Wisdom*, that the Parts of *Nature* are so harmoniously contrived and set together as to conspire to all kind of natural motions and effects without the extraordinary-immediate influence of the *Author* of it."

This particular philosophy led Nehemiah Grew to regard it as a pious duty to discover a mechanistic "cause" for each phenomenon; he defines "an *intelligible* account" as "such as is grounded upon the *Notions* of *Sense*, and made out *Mechanically*". This mental bias gave him an over-simplified conception of causation, and a "cause" became to him almost something tangible and visually imageable. He thought that "one property agreeing to divers Vegetables should have one cause : for although the scope and end may vary, yet the cause, as it is the cause of that property, must be one". His reasoning thus induced him to underestimate the fog of obscurity which always pervades the realm of causes, and which was even more impenetrable in those days, when biochemistry and biophysics were non-existent.

Grew was perennially sanguine, and he was apt to believe that he had succeeded in solving problems of causation before which the boldest spirits might quail even to-day. As an example we may take his answer to the question of *why* certain elements of plant tissues are elongated and cylindrical. "*Succiferous Vessels*," he says, "from their *Sal Alkali* grow in length ; for by that dimension chiefly this *Salt* always *shoots*. . . . And as by the *saline Principles* the *Vessels* are *long*, so by the *oleous* . . . they are *Cylindrical*" ; if it were not for the "oleous Principle" they would be flat or angular, "as all *saline* Shoots of themselves are, as those of *Alum*". The striking feature of this explanation is not that it happens to be in itself a failure, but that Grew at that early date should have made such a valiant effort after a causal-mechanical interpretation of form.

Grew's mechanistic theory of the universe had the very great advantage that it opened his mind to the mathematical aspects of biology. In 1620 Francis Bacon had lamented that "Nothing in Natural History is found to be . . . numbered up, nothing Weighed, nothing measured", and Nehemiah Grew, in his catalogue of the Royal Society's museum, published more than sixty years later, reiterates the same complaint ; for after noting that in his descriptions he had included the "just Measures", he adds, "Much neglected by Writers of Natural History".

Grew certainly took great trouble to give the exact dimensions of the specimens he studied, and many of the plates in this book are accompanied by a line divided into inches to show the degree of reduction of the drawings. Elsewhere he made the suggestion that the figures in herbals ought all to be "drawn by one *Scale* ; or at most, by Two ; one for *Trees* and *Shrubs* ; and another for *Herbs*". He realized that, for general descriptive purposes, words of more exact connotation than the "great" and "small", of the usage then current, were needed ; he proposed that leaves 5 in. or more in length should be called "great" ; 1–5 in., "mean" ; and 1 in. or less, "small".

When objects of very small size were in question, the biologists of the seventeenth century were faced with the difficulty of not having any adequate standards of measurement. For lack of these we find Grew using such terms of comparison as "about $\frac{1}{5}$th part as big as a *Cheese-Mite*", or "the breadth of a *Marsh-mallow-Seed* or little Spangle". From a twentieth-century point of view, units of this kind may seem wholly unscientific, but when people are forced to use them, in the absence of a more advanced technique, a certain degree of accuracy can be achieved. We may recall that, when the original pennyweight was defined in terms of grains of wheat, an effort was made to secure uniformity in the grains. A grain of sand, again, sounds to us now far too indefinite to be treated as a standard but Dobell has shown that Grew's contemporary, Leeuwenhoek, had in mind a grain of about $\frac{1}{100}$ in. in diameter, when he spoke of a "fine sandgrain", while a "coarse" grain was about $\frac{1}{30}$ in. In the case of objects seen through the microscope, the difficulty of size-recording was even greater. Grew observed, for example, that the vessels of roots showed a range of about twenty degrees in size, but he had no means of assessing these degrees individually, and all he could say was that "Some [vessels] in the *Vine*, being of the greatest Size ; appearing through a good *Glass*, at least one third of an Inch in Diametre". Grew indeed even resorts to the still more unsatisfactory expedient of naming some object the size of which was recalled by the size of the image as he saw it in its magnified form. For example, he describes the spore-case of the hart's-tongue fern, when seen through "a good *Glass*", as being "about the bigness of a Cherry-stone".

Grew not only tried to give measurements for the objects he describes, but he also recognized that "The *Arithmetick* of *Nature* is every where suitable to Her Geometry", and that the parts of the plant are "as punctually, for their Place and Number, composed together ; as all the mathematical Lines of a Flower or Face". Inspired by such ideas, he made an attempt to work out a mathematical description of leaf shape, on the theory that "all Regular *Leaves*, are defined or measured out by *Circles* ; that is, by the *Arches* or *Segments* of several *Circles*". He thought that the length of the leaf was "the *Standard Measure* for the *Diameters* of these *Circles* ; these being either its ull length, or certain equal parts subtracted, or multiplied". As, on the showing of his own figures, it required seven circles to define the simple leaf shape of the Cornelian cherry (*Cornus mas* L.), and as, even then, a large part of the outline failed to coincide with any of the circles, the whole scheme obviously broke down as soon as it was applied. Grew, however, was undoubtedly on the right lines in seeking for a mathematical expression for a physical phenomenon. He could not know that science was not yet in a position to help him towards answers to the questions set by his fertile and indefatigable mind. He was better served by current mathematical ideas when he came to realize that the permutations and combinations of a few characters might open up a range of differences comparable with the great "Variety, a few *Bells*, in the ringing of Changes, will produce". In discussing the tastes of plants, to which great attention was then paid as affording clues to their medicinal virtues, he gave a table showing how many threefold tastes would arise by the combination of ten simple flavours, each of which might be present in at least five distinguishable degrees of strength. He calculates that this would lead altogether to 1800 "sensible and defineable *Variations* of *Taste*".

Grew's appreciation of the importance of the virtues of herbs, with which as a physician he was much concerned, led him on to chemistry. With the aid of an apothecary whom he employed, he did a good many detailed quantitative experiments, setting before himself clear and specific aims. As an example we may cite a single one from among the problems which he tackled; he asks "whether any Plant growing in a Garden or the Field, doth not yield a lesser quantity of Lixivial Salt than another of the same kindred growing on the Sea-Coast; and with what difference?" To answer this question he "took *Garden* and *Sea-Scurvygrass*, of each lb. 1", and found that the former yielded "2 *Drachms* and 1 *Scruple*; the latter, being well washed, 9 *Drachms*, which is more than 4 times as much".

His view of the world as a mechanism not only inclined Grew to mathematical interpretations, but it also led directly to his wholehearted adoption of the atomic theory. He uses the word "principles" as synonymous with "atoms", which he regards as being indivisible, immutable, and of divers kinds. He says that "in the self same analogous way, as the *Letters* of the *Alphabet*, are the *Principles* of *Words*; so *Principles*, are the *Alphabet* of *Things*". He draws the logical conclusion that, if such unchangeable atoms are the structural basis of the world, "the *Formation* and *Transformation* of all Bodies, can be nothing else, but the *Mixture* of Bodies".

Whenever Grew grasped an idea, he did not let it go until he had wrung from it everything that, for him, it contained. The idea of atomicity, and the consequent significance of mixture, led him to certain conclusions which bore no fruit at the time, but which foreshadowed developments in science which did not actually come into being until the nineteenth century. One of these developments was the production of organic compounds in the laboratory. "Art it self", he says, "may go far in doing what *Nature* doth. And who can say, how far? For we have nothing to *Make*; but only to *mix* those *Materials*, which are already *made* to our hands. Even *Nature* her self, . . . *Maketh* nothing *new*; but only *mixeth* all things. So far, therefore, as we can govern *Mixture*, we may do what *Nature* doth." In another passage he is more specific about this hope: "we may be taught to *Imitate* the *Productions* of . . . *Vegetables*, . . . *Mucilage*, *Rosin*, *Gum*. . . . I do not say I can do all this: yet if, upon good *Premisses*, we can conclude this possible to be done; it is one step to the doing of it."

Another corollary, which Grew derived from his notions about atomicity and mixture, was concerned with the sexual process. Though he had never heard of a nucleus, and could not have had any conception of the actual nature of fertilization, he anticipated on general grounds the independence of the parental contributions in the fertilized egg. He emphasizes that "the most *perfect Mixture* of Bodies, can go no higher than *Contact*. For all *Principles* [that is, atoms] are *unalterable*; and all *Matter* is *impenetrable*. . . . In the most *visible*, and *laxe Mixture*, there is *Contact*; and in the most *subtile* and *perfect*, as in *Generation* it self, there is *nothing more*."

Nehemiah Grew's philosophy is sometimes dismissed as though it were merely second-hand Cartesianism; but though he was influenced by Descartes to some extent, it is doubtful if this influence went at all deep. It is significant that he parted company with Descartes altogether on the question of the structure of the universe. He was, as we have just seen, a confirmed atomist, whereas Descartes held the view that atoms do not exist.

Grew's whole personality seems to have been so closely integrated that his biological work, and his attitude to philosophical problems, were inseparably knit together. Great as were his specific contributions to the knowledge of plant structure, we are at least as much in his debt for his analysis of the relation between thought and observation, and for his recognition that the divorce of the two is fatal to scientific work. In his own words: "Thoughts cannot work upon nothing, no more than hands; he that will build an house, must provide Materials. And on the contrary, the Materials will never become an house, unless by certain Rules he joyn them all together. So it is not simply the knowledge of many things, but a multifarious copulation of them in the mind, that becomes prolifick of further knowledge."