Jeffreys, MacDonald, Munk, Columbo, Shapiro, and Runcorn. Despite this array of talent no generally acceptable theory emerged and the debate continued. In 1968 two young scientists at the University of Western Ontario, Mansinha and Smylie, reopened the question of excitation of the wobble by large earthquakes with the publication of a startling paper in which changes in the pole path were correlated with major earthquakes. They presented a theoretical explanation using the latest seismological data on the extent of the seismic source. Although questions were raised about the statistical validity of the correlation and the adequacy of the theory, the paper was sufficiently well founded to trigger a resurgence of interest in the problem.

The new theoretical and experimental results which emerged led to a NATO Advanced Study Institute at the University of Western Ontario in June 1969. This book, which represents the results of the conference, will become a standard reference work on the geophysical causes and consequences of polar motions. In a single volume one can find a review of the entire subject and specialized reviews as well as new results on the elastic theory of dislocation, the observation of deformation fields in the earth, the precise measurement and analysis of polar motion and rotation, and statistical correlation studies of the excitation of the Chandler wobble by different mechanisms. All told there are 28 articles, each followed by a transcript of the discussion.

Although the NATO Institute was stimulated by the revival of the earthquake mechanism for the Chandler wobble, the conferees chose not to validate this or any other hypothesis. The problem is still an open one which will undoubtedly receive much attention in the next few years. To paraphrase an earlier worker, the subject touches on every branch of geophysics. By the time it is covered, information will have been gained on air and ocean masses, atmospheric, oceanic, and bodily tides, elasticity and anelasticity of the earth's mantle, the earthquake mechanism, and the motion in the fluid core.

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Rational and International

The Metric System. A Critical Study of Its Principles and Practice. MAURICE DANLOUX-DUMESNILS. Translated from the French edition (1965) by Anne Garrett and J. S. Rowlinson. Athlone Press, London, 1969 (U.S. distributor, Oxford University Press, New York). x, 162 pp., illus. Paper, $2.50.

Prepare Now for a Metric Future. FRANK DONOVAN. Weybright and Talley, New York, 1970. 212 pp., illus. $5.95.

Britain and other Commonwealth countries have already undertaken conversion to the metric system, and the United States Congress has recently commissioned a study of the desirability and practicality of our country's doing so. English-speaking readers should therefore benefit from these two books expounding the history, principles, and practical usage of the system.

Danloux-Dumesnils's study commences with the chronological history and scientific development of the metric system. In 1790 Talleyrand urged that a plan for the unification of weights and measures be a joint Franco-British collaboration and declared it "an enterprise whose outcome must one day belong to the whole world." The British diplomatically refused. In the following ten years, the French pioneers in founding the system included Borda, Condorcet, Delambre, Fabbroni, Lagrange, Laplace, Lavoisier, Lefèvre-Gineau, Méchain, and Monge. A French law of 1795 initiated the metric system, one of 1837 made it fully effective, and a decree in 1961 repealed earlier legislation by adopting the modernized metric Système International, SI. The metric system was made legal but optional in use by the United States in 1866 and by Britain in 1897.

The principles underlying the system were (i) to use decimal numbers, not fractions, to count the units, (ii) to generate for each basic unit sub- and supersizes which differed in powers of 10, and (iii) to select the basic unit size for each property so that combination units also tended to be unity. The density of water expressed either in grams per cubic *centi*meter or in *kilo*grams per cubic *deci*meter was unity (1 cubic decimeter = 1 liter). Gauss in 1825 developed a coherent system of electrostatic units, and ten years later Weber continued it for electromagnetic units. In 1861 the British (William Thomson, Clerk Maxwell, and Latimer Clark) adopted electrical standards from which emerged the *cgs* (centimeter, gram, second) system. In 1913 the French proposed the *mks* (meter, kilogram, second) system. Finally in 1960 the General Conference of Weights and Measures modernized it to *SI* (meter, kilogram, second, ampere, Kelvin, candela), based on the 1901 proposal of the Italian Giovanni Giorgi to "rationalize" the units of electricity and magnetism. The International Bureau of Weights and Measures has preserved the metric standards since 1878 in their headquarters at Sèvres, France.

Danloux-Dumesnils undertakes critical analysis of measures in terms of unit concepts, dimensionality, precision, rationality, coherency, symbolism, comparability, calibrations, arbitrary and legal definitions, standards, norms, biological units, and subjective observations. He shows that because a measure is the combination of a counting number and a unit, for practicality the size of the unit should be so chosen as to keep the numbers small. He dislikes the 12 unit prefixes, from *tera*, 10^{12}, to *pico*, 10^{-12}, and suggests that we instead count in numbers. I might illustrate this—a resistance of 13.3 kiloohms might better be expressed as 13.3×10^3 ohms. My own restriction here would be that the exponents be multiples of 3. Many scientists, however, keep the number between 1 and 9 and vary the exponent: 1.33×10^4 ohms.

I cannot resist digression here by interjecting some noneuphonious combinations of prefixes and SI units (some derived), impractical as they may be: astraampere, attometer, femtofarad, gigagram, hectohertz, nanonewton, nembujoule, picopoise, teratesla. And in honesty I must remind the 135 kilomembers of the AAAS that each is urged to use the SI units in his published work (resolution passed 30 December 1970; see *Science* **171**, 711 [1971]). Oh well, many commendable endeavors have their humorous extremes. To continue reviewing:

Danloux-Dumesnils goes on to give technical descriptions of units for length, area, and volume (I hope "ca-

pacity" ceases to be a synonym for the last—it's an electrical property). Time units quite naturally raise considerations of reform by decimalization; the use of *hertz* for frequencies, radio waves, and musical scales is one of the matters in question. The mechanical units include for energy *joule*, which naturally is the unit for heat also. A whole chapter is required for the electrical and magnetic units. The history of thermometry is well done. Equally thoroughly described are optics, acoustics, and ionizing radiation.

After reviewing the Système International in the final chapter, Danloux-Dumesnils relaxes for a delightful monologue addressed, from his French base, to the British and North Americans, chastising them for their metric neglect. The appendix is 10^1 pages on logarithms—so essential in expressing, for instance, lengths from 10^{-15} meter for an atomic nucleus to 10^{20} meters for a galaxy. The index, footnotes, and reference documentation show reliable editing.

Danloux-Dumesnils does not discuss nonmetric units, conversion tables, machine, automobile, and air technology, or metric standards for dimensions of such goods as paper, lumber, and threads, subjects which are taken up by Frank Donovan in his book.

Prepare Now for a Metric Future is one of the first accounts of metric trends written for general readers in the United States. It is doubtful that any future account, welcome though it will be, will equal the style of Donovan's, which manages to be light and amusing as well as informative.

Donovan begins with a history of the various haphazard systems of weights and measures used throughout the world. Next is described the scientists' quest for a "natural basic unit," eventually leading to the metric system. Our Customary System and the metric system are then compared. The last half of the book describes metrication by various countries, especially modern Japan and Britain, and attempts by the United States. It concludes with a discussion of conversion for our metric future—"When, how, and how much."

Donovan makes his abstruse subject come alive for the nonscientific reader by colorful vignettes. Take, for example, the difficulties the scientists had in converting the suspicious French to the metric system about 1790. First of all, their surveyors were halted and often imprisoned. Did they not carry odd-looking instruments, and did they not dot the countryside with white flags? (White was the royal color.) Therefore they must be Bourbon agents engaged in overthrowing the government. Napoleon—hardly the champion of the metric system he is often pictured as being—did not enforce the system at home but only in the conquered countries, as one more way of Gallicizing them. As for the French at home, well, they were suspicious of those "long, foreign names of the new units, nor did they understand the prefixes, particularly those derived from Greek." It was not the Napoleonic wars that really spread the metric system but the Great Exposition held in London's Crystal Palace in 1851, which allowed European businessmen to compare their goods and ideas and to see the advantages that the scientists and educators had predicted for the universal metric system.

Metric symbol that British converts display on new goods, cartons, advertisements, and business forms. The symbol was designed by the British Standards Institute. Britain expects to complete its conversion to the metric system by 1975.

One last amusing tale Donovan tells is of Ferdinand Hassler, a mathematics instructor employed by the U.S. Treasury Department in 1830. On his own, with no legal sanction, Hassler decided to devise a complete set of standards of weights and measures for the United States. He then made a set of standards for each customhouse. Congress in 1838 asked that a complete set be sent to each state governor. This was not considered a permanent system at the time. Such is the origin of our Customary System, which some antimetrics think too hallowed by tradition to be replaced by the metric system.

Donovan illuminates the background of the great metric controversy in the United States which began early in the 19th century. "But for an unexpected adjournment of the first session (1902) of Congress, a bill would have been passed requiring all government departments to use the system exclusively." Even the *New York Times* admitted that the bill would certainly pass by a large majority. Donovan explains how a motion to adjourn Congress before the metric debate, followed by months of agitation against the bill by certain industries, defeated the attempt to establish limited metric standards at that time.

To convert the United States, at last, to the metric system would, it was estimated by one source in 1962, cost $11 billion. Dedicated to this effort is the Metric Association, whose former president, Fred J. Helgren, calculated that this cost could be covered in 16 years by eliminating the teaching of the Customary System in elementary arithmetic. Donovan claims a child can learn the simple metric units and how to move a decimal point in a few hours, thus gaining a a year or two for more constructive learning.

Donovan honestly includes the arguments against metrication, but maintains that thinking men almost unanimously believe that its adoption by the United States is inevitable. He quotes Edward Teller and Harold Urey in other supportive arguments.

The appendix has tables of the six basic SI units (modernized 1960 metric system), supplementary and derived units, and English-metric conversion factors. The index is useful, but the addition of footnotes and a bibliography would be helpful. For example, one would like to know who it was in the last century who admonished "the children of the Pilgrim Fathers" thus:

> When the gravediggers begin to measure our last resting places by the metric system, then understand that the curse of the Almighty may crush it just as he did the impious attempt to abolish the Sabbath.

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A History of π (Pi). PETR BECKMANN. Golem, Boulder, Colo., 1970. 190 pp., illus. $6.30.

Petr Beckmann, an electrical engineer with a penchant for mathematics and history, has written a very readable account of π from the time of ancient Egypt and Babylonia to the present—a period of about 4000 years. Such developments as the Archimedean classi-