has been written and edited with intelligence and love. The large-format pages are attractively designed. Seven hundred references are cited. And, as a rare final touch, the index is adequate.

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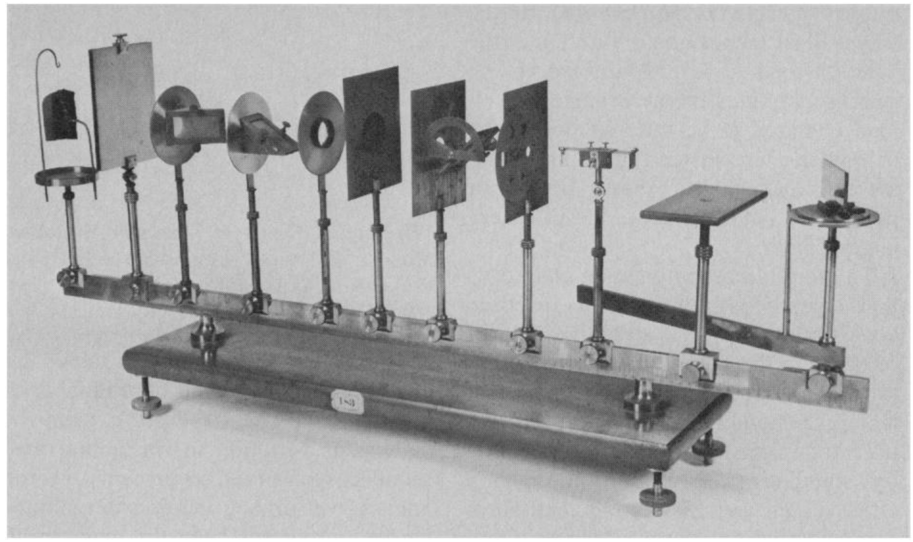


"An 'optical' bench for the study of the properties of radiant energy, signed: Ruhmkorff, rue des Orfèvres 6, Paris. The accessories are: heat source, bright brass screen, two prismatic cells, mica disk, black glass, aperture and mica sheet tiltable, aperture disk, thermopile, mahogany table, reflector on divided plate. The metre bar is divided to half-centimetres. . . . Base 680 × 88 mm; bar 1012 mm. 1845. *Teyler's Museum (183).*" [From *Nineteenth-Century Scientific Instruments*]

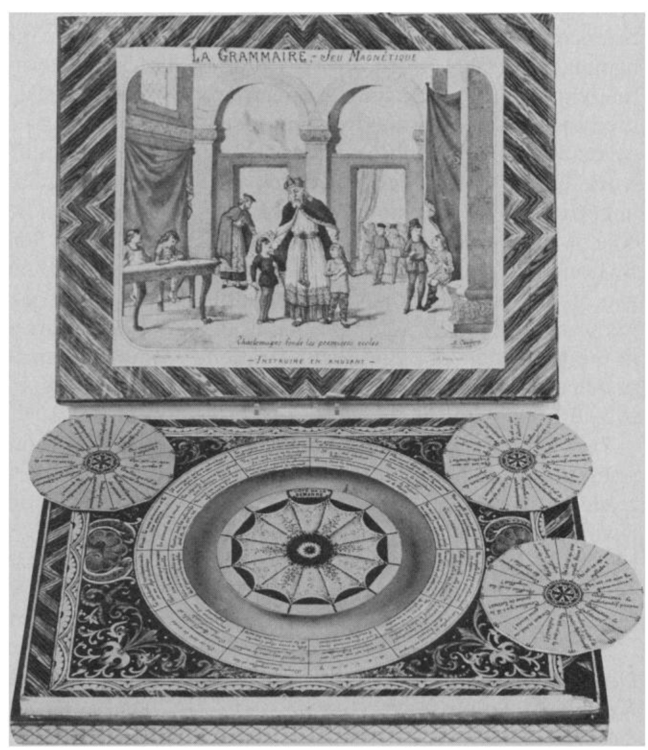
Apparatus of the Past

Nineteenth-Century Scientific Instruments. GERARD L.'E. TURNER. Sotheby Publications, London, and University of California Press, Berkeley, 1983. 320 pp., illus. $60.

The publication of a major book on 19th-century scientific apparatus is welcome. There is an obvious antiquarian as well as historical interest in these handsome examples of fine design and construction, hand made of brass and polished wood. In addition they are of practical interest to the teaching physicist. Despite natural breakage, the desire to replace old apparatus with state-of-the-art equipment, the temptation to use old apparatus as sources of parts for new research apparatus, and "leakage" from equipment storage rooms, a surprisingly large amount of 19th-century apparatus survives in colleges and universities. In my lectures I regularly use wave machines, a guinea and feather tube, electrostatic demonstration apparatus, and acoustical apparatus from the second half of the century because it does a better job of showing the phenomena than anything available today.

Turner's book is a series of well-executed compromises. He points out at the beginning that the subject of 19th-century scientific apparatus is a large one and he can, in the compass of a single volume, give primarily an overview and introduction to the subject. The apparatus Turner discusses and illustrates is drawn from the physical sciences (there is essentially nothing relating to what we would today call biology). Focusing still more narrowly, the bulk of the apparatus was used for physics or for closely related fields. After an introductory chapter and chapters on time and weights and measures, there is a series of eight chapters describing physics apparatus. Anyone who has looked at an older physics book will immediately recognize the familiar order of topics, starting with mechanics, hydrostatics, and pneumatics, going on to heat, sound, and light, and finishing with magnetism and electricity. Chemistry is given a relatively short treatment, which is perhaps a reflection of the fact that chemists use breakable glassware and so leave relatively few artifacts behind them, in contrast to physicists, who build in brass. The remaining chapters deal with various aspects of applied science such as surveying, navigation, calculation, and meteorology. The very last chapter, on recreational science, shows examples of scientific apparatus likely to be found in the 19th-century home.

The book is designed to be reasonably self-contained. The text that accompanies the more than 400 photographs and engravings gives enough background to place the apparatus in its proper historical and scientific contexts. There are useful short biographies of important scientists and instrument makers. Occasional misstatements do creep in: in the discussion of the work of Ångström on the measurement of the wavelengths of spectral lines, the statement is made that



"Game for teaching French grammar, employing a secret magnetic needle, and strips of iron embedded in three question disks. The magnetic needle points to the correct answer. Inscribed: la grammaire jeu magnétique—instruire en amusant. Box 295 × 230 × 35 mm. c. 1900. *Private collection.*" [From *Nineteenth-Century Scientific Instruments*] the wavelength is proportional to the angles of incidence and diffraction of the light (instead, it is proportional to the sum of the sines of these angles); Dollond is stated to be the inventor of the achromatic lens instead of its first commercial maker. But these are minor points in a balanced coverage of a very large subject.

To me the most interesting chapter is that dealing with instruments used in acoustics, which was an active field of research in the second half of the century. The illustrations suggest a number of lecture demonstrations that can still be used today. Examples are the sonometer, standing waves around the rim of a glass vessel, and Lissajous's method of compounding two simple harmonic motions at right angles to each other (although I suggest the use of a laser beam instead of an Argand lamp as a light source!). Turner has included photographs of a number of pieces of apparatus by the German-French acoustician and manufacturer Rudolph Koenig. Readers should look carefully at the Koenig devices for what we now call Fourier synthesis and analysis and marvel just how much excellent physics could be done in the era before the invention of the oscilloscope and other electronic devices.

American physicists from older colleges and universities who go through their own apparatus collections with Turner's book in hand will quickly appreciate that only British and Continental apparatus is illustrated. This is reasonable; Turner is senior assistant curator of the Museum of the History of Science at Oxford. Though American manufacturers are given only a passing reference, much of the simpler apparatus used in the United States was produced by manufacturers such as Pike of New York, Queen of Philadelphia (which also imported a good deal of apparatus), Ritchie of Boston, and Daniel Davis, Jr., of Boston. The omission of Davis leaves a gap, as Davis's electromagnetic apparatus was both widely sold and important in the understanding and demonstration of magnetism and the interaction of electric currents with the magnetic field.

This is a large-format, handsomely printed and bound book that invites the reader to browse a little, or a lot, but always to come back. It must be considered the definitive introduction to the study of 19th-century scientific apparatus.

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The Status of the Neutral Theory

The Neutral Theory of Molecular Evolution. MOTOO KIMURA. Cambridge University Press, New York, 1983. xvi, 367 pp., illus. $69.50.

The neutral allele theory of molecular evolution was proposed by a number of people in the late 1960's to explain the pattern of variation in the amino acid sequences observed in proteins. Motoo Kimura was among the first to embrace neutrality and has been the main architect of the theory in its present form. The theory asserts that "most" of the observed sequence variation in DNA and proteins both within and between species is due to the random fixation of nearly neutral alleles by genetic drift. Before neutrality, natural selection was routinely invoked to account for most of this variation. The neutral theory, even more than the observations of the variation itself, has had an emormous impact on population genetics, molecular biology, and our ideas about evolution. With the publication of a large number of DNA sequences over the past few years, acceptance of the neutral theory seems to have increased considerably. This theory is now invoked as routinely as selection was a few years back. The publication of this book is very timely, giving us a chance to review the theory in light of the old and new data and to judge the ability of the theory to account for evolutionary patterns at the molecular level.

The original arguments in support of the neutral theory included the constancy of the rate of evolution of proteins (the "molecular clock"), the almost random frequency of the amino acids found in proteins, and the apparent problems that genetic loads would pose if selection were solely responsible for the variation. Sixteen years later, Kimura uses these same arguments in a more developed fashion plus a number of new ones. In brief summary, Kimura uses the following observations as support for neutrality: (i) the approximate constancy of the rate of evolution of specific proteins or stretches of DNA; (ii) that those parts of protein or DNA molecules that are judged to be of less functional significance evolve more rapidly (so, for example, the third position of a codon evolves faster than the second); (iii) that substitutions that do occur tend to be conservative, causing little apparent disruption in the secondary or tertiary structure of the molecule; (iv) that codon usage in translated DNA tends to match the most abundant transfer RNA species available; and (v) that the frequencies of alleles in natural populations are similar to those predicted by the neutral theory. The basic arguments against selection are that selection is incompatible with all the observations listed above and that selection must entail enormous genetic loads to produce the patterns seen in the data. There are many other, less important arguments, but these capture the core of Kimura's justification for the theory.

Is Kimura's current defense of the neutral theory convincing? Not totally, perhaps not even in the greater part. Within Kimura's argument for the constancy of evolutionary rates, we learn that they are not, in fact, constant. The variance of the rates appears to be two to three times larger than expected under neutrality (Kimura calls those who worry about this "picayunish"). Even this variance may turn out to be an underestimate because of the technical difficulties of assigning mutations to remote branches of evolutionary trees. In addition, the rates of evolution are dependent on clock time, rather than on generation time, as required by the neutral theory. Kimura recognizes this as a serious problem. Since his original claim that the rate of mutation is proportional to the generation time has not been supported by subsequent data, Kimura now assumes that the generation time of a species is inversely proportional to the square root of its population size. Needless to say, there is no supporting evidence for this relationship either. The correlation between the perceived functional importance of a portion of a molecule and its rate of evolution is certainly in accord with neutrality and provides the most appealing argument for the theory. The codon usage story is the least appealing argument. Kimura argues that the fact that codon usage matches the most abundant transfer RNA is an example of stabilizing selection of nearly neutral alleles. However, he goes on to say that each species has its own characteristic frequency of usage of redundant codons. If the abundances of different tRNA's vary from species to species (for whatever reason), and if the codon usage