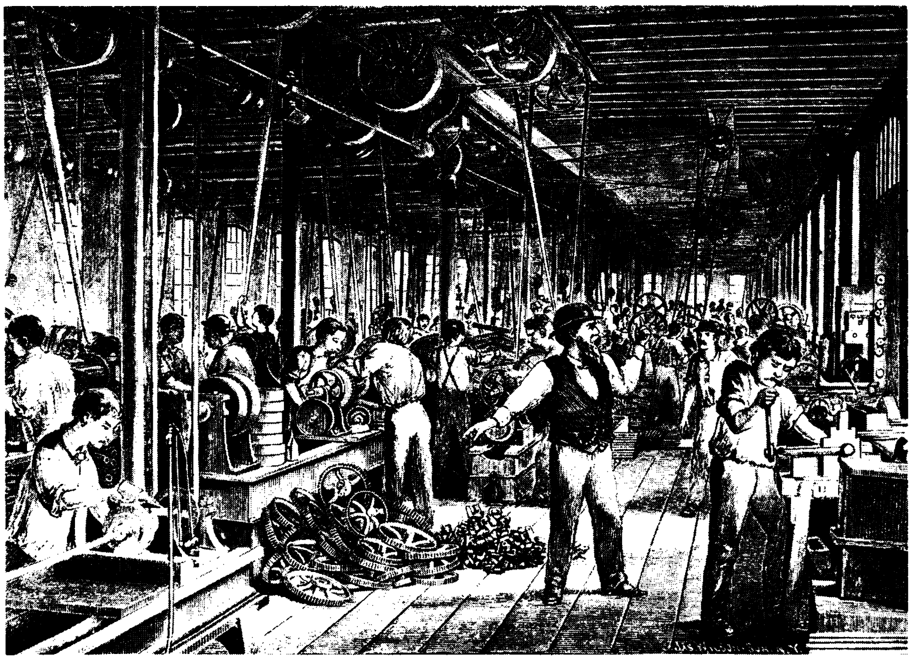

"Lathe and Press Room of the McCormick Factory, 1885. Note the clutter of the aisles and the materials handling methods." [*Illustrated Annual Catalogue*, McCormick Machines, McCormick Harvesting Machine Company, 1885; McCormick Collection, State Historical Society of Wisconsin. From *From the American System to Mass Production, 1800–1932*]

tion to the problem. It had dramatic positive effects upon productivity and equally dramatic, but negative, effects upon workers' job satisfaction. The assembly line represented a further step in the de-skilling of the work force that began with the American System.

Almost 90 pages, or about a quarter of the text, are devoted to two chapters on Ford. One deals with the evolution of the assembly line, the other with the switchover to the Model A. In the former, Hounshell discusses Henry Ford's experiments with his own brand of scientific management, Fordism, to shape production methods and the assembly line to achieve production goals with the Model T. The latter chapter, however, breaks with the theme of the book. The focus is no longer interchangeable parts and mass production, but rather Fordism, the personnel involved in the introduction of the Model A, and the production problems that Ford experienced as a result. Consequently, the reader is left unsure whether Ford's problems in 1928 are intended as providing grounds for a general indictment of the mass production system or seen as just a reflection of arrangements at Ford.

Neither the theme nor the form of the study is maintained in the concluding chapter, "The ethos of mass production and its critics." It does not advance the author's argument, nor does it summarize it; rather, it is an examination of what popular culture had to say about mass production together with a brief digression on the application of that technique to prefabricated housing. This chapter also provides the justification for the study's terminal date, 1932. This was when Diego Rivera painted his wall murals, *Detroit Industry*, at the Detroit Institute of Arts. I would have preferred that the author condense both this chapter and the preceding chapter on Fordism as part of a new concluding chapter. Nevertheless, both the armchair historian and the specialist in the history of technology will find this a highly readable and most informative work.

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Earth History

The Chemical Evolution of the Atmosphere and Oceans. HEINRICH D. HOLLAND. Princeton University Press, Princeton, N.J., 1984. xii, 583 pp., illus. $75; paper, $24.50. Princeton Series in Geochemistry.

The continuity of life during the past 3.8 billion years "is a consequence of the relative dullness of Earth history, of the rarity and relatively small magnitude of disruptive events such as asteroid impacts, of the variety of physical and chemical control mechanisms that have tended to maintain the status quo." With these words Holland summarizes his basically uniformitarian outlook on Earth history. The physical environment at Earth's surface changed radically and rapidly during the first half billion years after Earth's formation, during which time the atmosphere formed and the oceans grew to nearly their present size. Since that time atmospheric pO_2 has risen and pCO_2 has declined while the chemistry of seawater has remained remarkably constant. Holland supports this thesis with voluminous quantities of data on the chemical and isotopic composition of evaporates, shales, iron formations, paleosols, uraninites, and various other types of sedimentary rocks. Very few of these data are easy to interpret, however. Thus, despite the clarity with which the arguments are presented, this book will probably provoke considerably more controversy than Holland's very useful companion volume on the chemistry of the present ocean-atmosphere system.

The first four chapters of the book deal with the period from the beginning of the accretion process until the formation of the oldest rocks. Holland uses thermodynamic arguments to show that the oxidation state of volatiles released from Earth's interior depends critically upon the abundance of elemental iron in the crust and upper mantle. In accordance with recent work on the dynamics of accretion, Holland proposes that core formation occurred early, so that any highly reduced primitive atmosphere must have been extremely short-lived. Thermodynamic arguments are also used to estimate the partitioning of volatiles between the atmosphere and the (molten) mantle during the accretion phase. Very little atmospheric water vapor is predicted because of its high solubility in silicate melts, but as much as one-third of Earth's total CO_2 inventory may have been present in the gas phase at the close of accretion. These latter conclusions appear somewhat weak, since it is not clear to what extent equilibrium would have been maintained during the accretion process. Holland's fondness for thermodynamics is again apparent in his discussion of primitive atmosphere composition, despite his acknowledgement that atmospheric chemistry is controlled primarily by kinetic processes.

The next four chapters, which deal mostly with the time period from 3.9 to 0.6 billion years before the present, cover a wide range of topics, including the implications of observed weathering patterns for atmospheric pCO_2, the interaction of seawater with hot mid-ocean ridge basalts, variations in dolomite abundance and in the composition of shales, and the rise of atmospheric oxygen. Here is where Holland's uniformitarian viewpoint becomes apparent. The relative constancy of the lithium content of shales is used to discount the idea that the chemistry of the early oceans was dominated by hydrothermal fluxes and that the early oceans were buffered by large-scale interaction of seawater with ocean floor basalts. Evidence from paleosols and detrital uraninite deposits is used, along with data on the manganese content of carbonates and inferences on the availability of sulfate, to argue that atmospheric pO_2 remained at a roughly constant level of 0.02 of the present atmospheric level (4×10^{-3} atmospheres) throughout the time period from 3.0 to 1.5 billion years before the present. This interpretation contrasts sharply with that of other recent workers, who see major increases in pO_2 at 2.4 billion years and 1.7 billion years before the present. Holland suggests that the oxidant required to precipitate banded iron formations and to oxidize iron in ancient soil horizons was, in both cases, atmospheric O_2; these are just two examples of specific points about which prolonged debate is likely to flourish.

Holland's discussion of the Phanerozoic is necessarily compact but contains a nice synopsis of the mechanism by which oxygen is transferred between carbonate, sulfate, and atmospheric reservoirs. Biological innovations leading to greater productivity in the oceans and colonization of the continents are suggested as the principal cause of increases in atmospheric pO_2 since the late Proterozoic. Biological evolution is also invoked to explain the scarcity of dolomite deposits during the last 150 million years; Holland suggests that this phenomenon is linked to the decreasing abundance of intertidal and subtidal algal mats. The possible role of an impact event in causing mass extinctions at the end of the Cretaceous is mentioned briefly but enthusiastically.

In summary, many workers in the field of Earth history will probably disagree with parts of Holland's analysis, but they should all become acquainted with it. Dense with facts, cautious in its interpretations, and laced with interesting speculations, Holland's book will be a valuable reference for geochemists, geologists, and atmospheric scientists for years to come.

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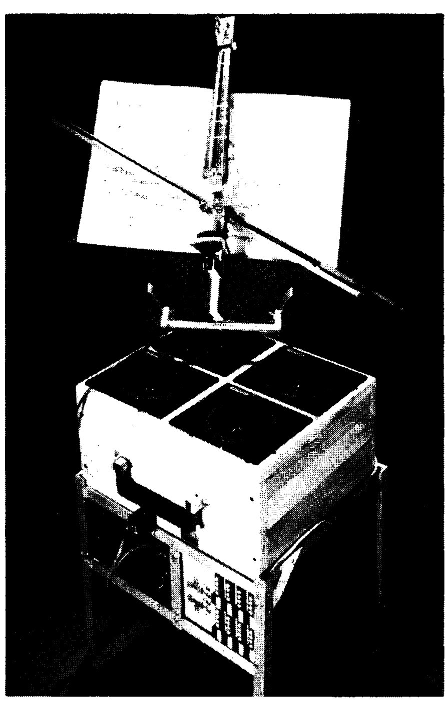
The Sound of Music

The Science of Musical Sound. JOHN R. PIERCE. Scientific American Library, New York, 1984 (distributor, Freeman, New York). xiv, 242 pp., illus., + two records. $27.95.

This lavishly illustrated introduction to musical acoustics demonstrates once again the wide-ranging wisdom, infectious enthusiasm, and unique flair for rendering the complex comprehensible that John Pierce has manifested in numerous earlier scientific books (not to mention several science-fictional entertainments under the pseudonym J. J. Coupling). Undaunted by two retirements—first from the Bell Telephone Laboratories and subsequently from the California Institute of Technology—the irrepressible Pierce continues an active interaction with the world's leading centers for computer research in music and acoustics, especially Stanford's CCRMA, and a playful exploration (with Elizabeth Cohen and Max Mathews) of new musical scales based on computer-synthesized tones whose partials depart from the usual harmonic series.

It was under Pierce's auspices at the Bell Laboratories that Mathews (to whom this book is dedicated) developed his series of increasingly powerful and versatile computer programs, culminating in Music V. Mathews's programs have enabled composers, psychoacousticians, and perceptual psychologists to generate for the first time any specifiable sound, unfettered by the limitations of existing musical instruments or physical devices. As this book attests, the worlds of music and psychoacoustics have been forever transformed.



Max Mathews's electric violin, which can simulate the sounds not only of a good violin but of brass instruments. [Photo courtesy of M. V. Mathews; from *The Science of Musical Sound*]

Not only can one now closely simulate the sounds of real trumpets, violins, bells, or drums, one can parametrically interpolate between such instruments, changing by degrees a violin into a trumpet, or a flute into a human voice. One can also synthesize completely novel sounds and, by independently varying the frequencies of the sinusoidal components and the overall amplitude envelope, produce paradoxical illusions in which a tone that seems throughout to be falling in pitch is clearly much higher at the end than it was at the beginning.

Readers can hear a number of these auditory phenomena on two thin phonograph disks that are included, along with nine informative appendixes, at the back of the book. The demonstrated phenomena are more than amusing tricks; they have influenced contemporary musical composition, and they have made it possible to determine which of the vast number of physical variables of musical sounds are perceptually salient. Thus, whereas the steady-state spectral energy distribution had been thought since Helmholtz to determine the characteristic tone quality or timbre of a particular musical instrument, Grey, Risset, Wessel, and others have shown that the temporal variations in attack and decay of the individual partials of a tone are just as important.

Pierce enlivens his presentation with illuminating historical commentaries, personal anecdotes, photographs, and "microbiographies" of contemporary notables in the fields of electronic and computer music (including Babbitt, Boulez, Chowning, Stockhausen, Ussachevsky, and Varèse) and in the fields of acoustics and psychoacoustics (including Békésy, Fletcher, Schouten, Schroeder, Stevens, and Sundberg). Particularly enlightening is his recounting of the vicissitudes of the science of architectural acoustics from its turn-of-the-century founding by Harvard mathematics professor Wallace Sabine, through the acoustical disaster of Philharmonic Hall in New York's Lincoln Center, to the salvation of that structure as the present Avery Fisher Hall by Cyril Harris.

How can something as subjective as the quality of musical sound be made a science? Of the many advances in this direction described by Pierce, I can give