During the 1970s these high hopes gradually faded. The simplest grand unified theories were found to underpredict the lifetime of the proton. Massive neutrinos began to seem less than ideal candidates for the invisible gravitating mass. But the heaviest blow came from the simultaneous discovery in 1974, by G. t'Hooft and A. M. Polyakov, that nearly all grand unified theories predict a hugely excessive production of superheavy magnetic monopoles in the early hot universe. It was these and related historical developments (none of which is mentioned by Lightman and Brawer) that set the stage for the series of theoretical studies that culminated in Alan Guth's 1981 paper on inflation. As Steven Weinberg mentions in his interview, particle physicists welcomed inflation primarily because it offered a cure for the fatal disease of over-copious magnetic-monopole production in the early universe.

It is true that Guth also stressed the flatness and horizon problems. But, as several of the theorists remark, the solutions to the flatness and horizon problems offered by the inflationary model are not only less important but also more problematic than the solution of the magnetic-monopole problem. Dennis Sciama (p. 149) gives a characteristically lucid account of an argument he attributes to Roger Penrose: Inflation doesn't guarantee large-scale homogeneity, for "if the small scales are very rough and they're pulled out to larger scales, the larger scales are rough" (p. 148). As for the "the question of why the universe began with its gravitational energy and its kinetic energy of expansion so closely balanced," the need for fine tuning disappears, as Steven Weinberg points out (p. 459), when one talks about spatial curvature rather than the kinetic and gravitational energies of the universe (neither of which, incidentally, has a well-defined meaning in the cosmological context). The question then becomes, Why is the radius of curvature deduced from current estimates of the cosmic mass density comparable in magnitude to the radius of the theoretically observable universe? Inflationary cosmology evades rather than answers this question: it predicts a value of the cosmic mass density five to ten times higher than current estimates.

Lightman and Brawer not only ignore the chief argument in favor of inflationary cosmology. They also ignore what many theorists consider to be the most serious difficulty with any theory that invokes spontaneous symmetry-breaking phase transitions: the so-called cosmological-constant (or vacuum-energy) problem. Every symmetry-breaking phase transition causes the vacuum energy density to decrease by an amount that is immensely greater than the present cosmic energy density. Inflationary cosmologies based on standard particle physics require the cosmic mass density (related to the cosmic energy density by Einstein's mass-energy relation) to decrease, in three independent steps, from an initial value of order 10^{80} g cm^{-3} to its present value, which is certainly less than 10^{-29} g cm^{-3}. Here is fine tuning of an initial condition with a vengeance!

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West Orange Works

Edison and the Business of Innovation. ANDRE MILLARD. Johns Hopkins University Press, Baltimore, 1990. xvi, 387 pp., illus. $38.50. Johns Hopkins Series in the History of Technology.

By 1887, 40-year-old Thomas Edison had already accomplished the work of many lifetimes. He had created the electric light, power, and electrical manufacturing industries, made major contributions to telegraphy and telephony, and, with his most original invention, the phonograph, heralded future entertainment and consumer product revolutions. What would he do for an encore?

He would, Andre Millard explains, devote his remaining 44 years to the "business of invention." He would build an "invention factory" at West Orange, New Jersey, ten times as large as any other laboratory in the United States. There he would start by carrying out contract research for other companies, until he had made enough inventions to spawn a new industrial empire.

This central place for invention flew in the face of business wisdom. "Pioneering don't pay," Andrew Carnegie had concluded. Modern experts, including Millard, agree. Invention must be meshed with the needs of sound design, productive manufacturing, and customer-responsive marketing if a company plans to make money.

Edison did not scorn money-making, but he put it in its place. Business or lives should not, he said, be measured solely by "the metronome of money." For him, invention, as both achievement and culture, set the tempo. Money-making only proved the success of past inventions and financed future ones.

The strength of Millard's book is his evocation of this "machine shop culture." Edison sought, against the current of the times, to keep it as central to the process of invention in the 20th century as it had been in the 19th. It was built around experiment-

Manufacture of talking dolls in Edison's Phonograph Works, about 1890. "With [his] dictating machine in trouble, Edison looked to the doll to keep the business afloat. . . . There was nothing wrong in the marketing strategy; the talking doll proved to be so popular that orders soon out-stripped supply. The problem was in the small phonograph movement inside the dolls. The diaphragm/stylus assembly simply would not stay in the fine groove of the wax record. Consequently most of the dolls failed to work properly, steadfastly refusing to talk for their owners. One dealer reported that 188 dolls were returned out of 200 sold." [From *Edison and the Business of Innovation*] ers ("muckers") valued for their ability to combine skills of both hand and head. Their autocratic boss walked the shop, spitting on the floor, joking, questioning trying his own hand, ceaselessly challenging, criticizing, cajoling, inspiring, perspiring.

But it was all, Millard points out, something of an illusion. Edison reputedly staked everything on great campaigns: round-the-clock efforts to perfect the phonograph, assembling great machines to concentrate the low-grade iron ore of New Jersey. But the main profits came from humbler applications of invention: the nickels put in Edison phonograph nickelodeons or Edison "peep show" Kinetoscopes and a concrete business spun off the iron ore disaster. By the 1920s, the West Orange laboratory was a service organization for perfecting such products, not a group of pioneers looking for new ones.

Millard shows Edison losing leadership in the phonograph industry, blowing millions on the iron ore mining process, succeeding only briefly in pioneering and monopolizing motion pictures, and introducing a storage battery so defective he bought it back from customers rather than sully the Edison name. Analytical chapters (unfortunately poorly supported with numbers on sales, profits, and employment) highlight the clash between the company's adoption of modern business methods and the persistence of Edison's absolute authority. The book fits into the gap on the Edison bookshelf between Byron Vanderbilt's *Thomas Edison Chemist*, which more fully treats the science and technology of Edison's later work, and Matthew Josephson's lively yet accurate biography. It complements the best study of Menlo Park, Robert Friedel and Paul Israel's *Edison's Electric Light*, which shows how well the very Edisonian methods that failed so often at West Orange could work when the time and challenge were right.

But do not dismiss the later Edison. Like the young wizard, he dared greatly and lived fully: dodging ore boulders, shepherding dancing girls, pugilists, or Buffalo Bill through his "Black Maria" movie studio, and, in 1906, worn out and ill from too many great campaigns, mounting yet another to perfect that battery, long after any sensible businessman would have written it off. Picture him at the bench after thousands of failed experiments, stout, bent, white-haired, tired, deaf, and desperate, a hero in the mold of Tennyson's aging Ulysses "made weak by time and fate, but strong in will," determined "to strive, to seek, to find and not to yield." He and his muckers did find a scientifically improbable combination of nickel flake, graphite, and lithium that saved the battery. He never did yield. He was looking for revolutionary ways to make rubber from goldenrod plants a few months before his death in 1931. Millard sensibly focuses on analyzing the business. But Edison the man, an exasperating, never-satisfied Ulysses of invention, shines through.

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Amusement arcade with Edisonian devices, San Francisco, 1894 or later. At left are coin-slot phonographs, with ear tubes dangling; at right are peephole Kinetoscopes. "The Kinetoscope was a hurried first attempt to get moving pictures into a form suitable for commercial exploitation. It was closely modeled on the coin-slot phonograph, which was the only part of Edison's talking machine business to experience any growth of sales in the gloomy years after 1892." [From *Edison and the Business of Innovation*]

Dividing Cells

Meiosis. BERNARD JOHN. Cambridge University Press, New York, 1990. xii, 396 pp., illus., $89.50. Developmental and Cell Biology Series.

Meiosis was one of the first topics covered in my introductory college biology class. It is a fundamental property of most eukaryotes and is basic to sexual reproduction. In fact, Mendelian genetics is a formal explanation of the events of meiosis. Despite this familiarity, meiosis has received much less attention from molecular biologists than its partner, mitosis. One reason for this may be that the majority of the literature of meiosis is classical cytogenetics and is relatively inaccessible to molecular biologists looking to place their work in the broader context. This book by John, an established expert in the study of meiosis, should thus be welcomed in the hope that it will serve as a cornerstone in defining problems awaiting genetic and molecular solutions.

John offers a broad, largely historical survey of the literature for both animals and plants. The topics he chooses are interesting and appropriate. Meiosis, despite (or perhaps because of) its fundamental role in eukaryotic life, is a widely varied phenomenon, and its outcome of genetic continuity with diversity is reached by an assortment of mechanisms. Most of us think of conventional, chiasmate meiosis, with well-behaved chromosomes and tidy steps. Although the majority of organisms have this chiasmate version, many are achiasmate entirely, in one sex, or for a particular chromosome. Other organisms invert the sequence of the two divisions, placing the equational division before the reductional division. For readers accustomed to conventional meiosis these variations may be surprising; John presents them well, both in text and in diagrams. These variants serve as a reminder that not everything will be learned from our selected model organisms. Even in organisms with chiasmate meiosis, many of the elementary processes are still poorly understood. In reminding us of how little we really do know the book is very successful.

Ultimately, however, the book fell short