much he may have required her sexual favors) he could not accept her lack of education. Hess's financial demands were matched by Nobel's insensitive condemnation of her background.

Increasingly, Nobel had to contend with a hostile press, which often labeled him a merchant of death. Despite his close friendship with Bertha von Suttner and great sympathy with her peace movement, which no doubt influenced the formulation of his testament, Nobel was hardly a pacifist. He firmly believed that weapons of mass destruction, such as those he worked on, would be the ultimate deterrent, to the extent that in 1890 he wrote: "On the day when two armies will be able to annihilate each other in one second all civilized nations will recoil from war in horror and disband their forces."

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Quantum Mysteries

The Quantum Theory of Motion. An Account of the de Broglie–Bohm Causal Interpretation of Quantum Mechanics. PETER R. HOLLAND. Cambridge University Press, New York, 1993. xx, 598 pp., illus. $120 or £70.

How can electrons behave sometimes like particles and sometimes like waves? How does an atom know, when it passes through one slit of a double-slit apparatus, that the other slit is also open, so that it should behave so as to contribute to an interference pattern? How does a radioactive atom know when to decay? How can electrons tunnel across classically forbidden regions? How can Schrödinger's cat be simultaneously dead and alive—but only until we look at it and find that it is one or the other?

Quantum mechanics is undoubtedly our most successful scientific theory. At the same time, it is a bizarre theory, so bizarre that, according to Richard Feynman, a master of quantum calculation, "nobody understands quantum mechanics." The features that primarily contribute to its strangeness are its indeterminism and, even more, its apparent subjectivity, its constant appeal to measurement and to the observer, as codified in Bohr's Copenhagen interpretation. One of the clearest statements on this subjectivity is that of Heisenberg: "The idea of an objective real world whose smallest parts exist objectively in the same sense as stones or trees exist, independently of whether or not we observe them . . . is impossible." The subjectivity and indeterminism of quantum theory have quite naturally been accompanied by the view that quantum particles do not really have trajectories and that, by Heisenberg's uncertainty principle, any talk of such things is meaningless. In their famous textbook on quantum mechanics Landau and Lifshitz declared flatly that the interference effects in the double-slit experiment "can in no way be reconciled with the idea that electrons move in paths." It is true that strong disapproval of this state of affairs was expressed by some prominent physicists, most notably Einstein, who believed that "the essentially statistical character of contemporary quantum theory is solely to be ascribed to the fact that this [theory] operates with an incomplete description of physical systems." Nonetheless, for several decades it was believed by most physicists that the mathematician John von Neumann had proven, with the utmost mathematical rigor, that a return by physics to any sort of fundamental determinism was impossible. For example, according to Max Born, who formulated the now standard statistical interpretation of the wave function, von Neumann had shown that "no concealed parameters can be introduced with the help of which the indeterministic description could be transformed into a deterministic one."

The "proof" of von Neumann and the claims of Born, Landau and Lifshitz, Heisenberg, and Bohr notwithstanding, in 1952 David Bohm, through a refinement of de Broglie's pilot-wave model, succeeded in providing an objective and completely deterministic account of quantum phenomena. This achievement was greeted by most physicists with indifference, if not outright hostility. John Bell, of Bell's inequality fame, was a refreshing exception. Bell expressed his reaction as follows:

> In 1952 I saw the impossible done. It was in papers by David Bohm. Bohm showed explicitly how parameters could indeed be introduced, into nonrelativistic wave mechanics, with the help of which the indeterministic description could be transformed into a deterministic one. More importantly, in my opinion, the subjectivity of the orthodox version, the necessary reference to the "observer," could be eliminated. . . . But why then had Born not told me of this "pilot wave"? If only to point out what was wrong with it? . . . Why is the pilot wave picture ignored in text books? Should it not be taught, not as the only way, but as an antidote to the prevailing complacency? To show us that vagueness, subjectivity, and indeterminism, are not forced on us by experimental facts, but by deliberate theoretical choice? [*Speakable and Unspeakable in Quantum Mechanics* (Cambridge Univ. Press, Cambridge, 1987), p. 160]

The Quantum Theory of Motion is the first book to appear that is devoted solely to a systematic presentation of Bohm's pilot-wave formulation of quantum mechanics, a precise, deterministic, microscopic theory describing a motion of particles under an evolution choreographed by the wave function. Here the reader will find detailed answers to the many questions prompted by quantum theory.

Novel resolutions of the quantum mysteries regularly appear. Most cannot withstand careful scrutiny. It is therefore worth emphasizing that the explanations found in Holland's book are genuine. In particular, they are not evasions, in which the real problems are skirted rather than solved. Moreover, as Holland points out, Bohm's theory is "very much a 'physicist's theory' and indeed puts on a consistent footing the way in which many scientists instinctively think about the world anyway."

One very striking and much discussed implication of quantum theory, that of quantum nonlocality, remains in Bohm's account, not as a mystery but as a natural consequence of the mathematical structure of quantum theory itself. In this sense, while the quantum paradoxes are *eliminated* by Bohm's theory, nonlocality is *explained* by this theory. Holland quite appropriately devotes much attention to quantum nonlocality, delineating how it emerges in the quantum theory of motion.

In fact, one has to do astonishingly little to textbook quantum theory in order to transform it into a theory—Bohm's theory—in which the quantum paradoxes are not merely resolved but are eliminated entirely. This simplicity does not shine forth in Holland's presentation, however, but is often obscured by an elaboration of details. Holland provides detailed computations and descriptions of trajectories, quantum forces, and quantum potentials—a description often involving precessing spins and gyrating rotators—for a large variety of situations. Although these details are interesting and are undoubtedly of some value, pedagogical and otherwise, they are often unnecessary and tend to make it difficult to appreciate the essential point of Bohm's account: that the origin of the quantum paradoxes lies neither in quantum phenomena nor in the quantum formalism that governs these phenomena but rather in the quantum philosophy, expressed in the Copenhagen interpretation of quantum theory, with which the quantum formalism has been encumbered. Almost as soon as one dispenses with this philosophy and instead posits that particles have positions regardless of whether or not they are being observed, one arrives at Bohm's theory, which succeeds in completely accounting for all (nonrelativistic) quantum phenomena while avoiding the quantum paradoxes, not so much because of the detailed character of the trajectories that it defines as because of the mere existence of these trajectories.

The level of presentation in this book is not elementary; a solid background in quantum theory would be extremely helpful. On the other hand, the wealth of details and literature citations make this a valuable reference work with which anyone with a serious interest in the foundations of quantum mechanics should become familiar. Despite his strong advocacy of a particular theory, Holland comes across as refreshingly open-minded. He concludes that "we are in a period of transition between two great world views—the universal machine of the classicists and a new holistic universe whose details we are only beginning to glimpse. The end is not in sight for theoretical physics."

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Vignettes: Medical Trends

In ten of the twelve instances in which chloral hydrate, the bromides, sulfonal, and trional are used for therapeutic purposes [in Agatha Christie's novels], they appear in works published between 1920 and 1940. By contrast, the appearance of barbiturates and Christie-simulated barbiturates are more evenly distributed throughout her writing career: novels published between 1920 and 1940, three; 1941 and 1960, two (and *Curtain*, written in the early 1940s but delayed for publication until 1975); and 1961 and 1976, two.

—*Michael C. Gerald*, in *The Poisonous Pen of Agatha Christie* (University of Texas Press)

The canonical chromosomal sex of humans—the XX female and XY male—is not as rigid as we sometimes think. It is important to keep in mind that in the United States sexually ambiguous babies are "fixed" at birth. (Endocrinologists make these babies mostly into girls; urologists make mostly boys.)

—*Londa Schiebinger*, in *Nature's Body: Gender in the Making of Modern Science* (Beacon)

The New Genetics

Human Gene Mutation. DAVID N. COOPER and MICHAEL KRAWCZAK. Bios Scientific, Oxford, U.K., 1993 (U.S. distributor, Books International, McLean, VA). xiv, 402 pp., illus. $99 or £49.50.

A book on human mutation is clearly overdue given the major discoveries that have occurred in the field within the last 15 years, the era in which recombinant DNA technology has been applied to human genetics. In the traditional Mendelian view chromosomal genes are transmitted in a stable manner from generation to generation. As recently as 15 years ago there was thought to be a one-to-one correspondence of the gene and its protein product, and the range of mutations causing disease was limited to point mutations, deletions, duplications, and other rearrangements affecting the coding regions of genes or *cis* sequences in close proximity to them. Recombinant DNA technology revealed that our understanding of human genetics was incomplete at best and in some cases just plain wrong.

For example, in 1977 the discovery of intervening sequences (introns) in genes between protein coding blocks that must be accurately removed by splicing at the mRNA level in order to connect the coding blocks showed the idea of linear correspondence of gene and protein product to be incorrect. A more recent surprise was the realization of the great distance over which *cis* sequences can act. Alterations in so-called locus control regions eliminate the expression of entire families of genes, including members that are placed 50 to 75 kilobases downstream. Likewise, sequences repeated at great distances from each other can mispair, leading to crossing-over events that produce deletions, duplications, or inversions of millions of base pairs.

New modes of inheritance and unusual types of human mutation were added to the classical view and greatly altered the perspective of human geneticists. Mendelian inheritance remained, but the old laws were broken by new forms of non-Mendelian inheritance, including the maternal inheritance of mitochondrial DNA, the inheritance of two copies of a chromosomal homolog from one parent and no copies from the other (uniparental disomy), the two-stage inheritance of expanding trinucleotide repeats, the inheritance of disease from an unaffected parent owing to germinal mosaicism in that parent, and the role of somatic mutation in carcinogenesis.

Mutations in mitochondrial DNA can either be passed through the maternal germ line or originate in somatic cells and cause a variety of diseases (for example, chronic external ophthalmoplegia). Rarely, uniparental isodisomy can lead to inheritance of an autosomal recessive disease when only one parent is heterozygous for a defective gene. That parent may provide two copies of the chromosome bearing the defective gene while the other parent makes no contribution. This unusual form of inheritance has now been observed in a number of conditions, including cystic fibrosis. When an individual has germinal mosaicism he or she has two populations of gametes, one normal and the other affected with a mutant gene. Five to 10 percent of "new" cases of autosomal dominant diseases (for example, osteogenesis imperfecta) are due to germinal mosaicism, and the parents face a significant risk of disease recurrence in subsequent offspring.

Examples of surprise mutations include the aforementioned expansion of unstable repeats, genomic imprinting, and retrotransposition of mobile elements. Unstable trinucleotide repeats that can change in size from one generation to the next or even from one mitosis to the next have been found to cause six diseases (including the fragile X syndrome), and the list has just begun. These mutations can inactivate genes through expansion of the repeats. Occasionally the repeat number may contract, reverting the disease gene to a normal gene. A sizable portion of the genome is subject to imprinting, in which one copy of a gene is inactivated while the other remains functional. Which copy is inactivated depends on its parental origin. We are just beginning to learn of diseases whose etiology is related to mutations that disrupt normal imprinting (for example, Beckwith-Wiedemann syndrome and Wilms tumor). Mobile repeated elements, notably L1 and Alu, have been observed to retrotranspose through an RNA intermediate from their normal genomic location into a new site, occasionally producing disease (for example, hemophilia A).

Another surprise for human geneticists is the ease with which known mutations can