activities. The scientific establishment, educators, and legal action groups, in turn, have become better organized for explaining the difference between science and non-science in school curricula.

More subtly, according to Larson, judges have responded to popular opinion in finding anti-evolution and creation-science statutes repugnant to "the modern mind." Judges have shown deference toward greater public acceptance of the methods and social meanings of science in the United States. In so doing, it might be added, they have acknowledged a vital connection between scientific inquiry and the civic and social purposes of education in a democratic society. They have protected that connection against groups demanding a similar legitimacy for their own preferred systems of belief. In the political calculus that underlies "public science," the principle of majority rule has shifted the balance of power in controlling school curricula since the 1920's. Several strands of historical change help to explain this shift, notably demographic movements, political realignments, and higher levels of scientific education in the populace. Creationists, for their part, have shown an awareness of the shift as they have attempted to present traditional doctrines in scientific garb and, as a minority, to claim that without "equal time" their rights are being infringed upon, an argument that so far the courts have rejected.

What the author finds most interesting, and describes well, is the resourcefulness of the proponents on both sides as they have countered each other's strategies repeatedly in legislative chambers and courts of law. Since the contention is not likely to cease, this book merits attention for its many insights into the dilemmas of science education in a democratic society.

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The Character of Science

Changing Order. Replication and Induction in Scientific Practice. H. M. COLLINS. Sage, Beverly Hills, Calif., 1985. viii, 187 pp. $25; paper, $12.50.

The most difficult task of the scientist is to suspend judgment about what is true and what is not. This is precisely the task Harry Collins asks us to attempt in reading his important little book. The request is not made lightly. Public trust in science can only be maintained, Collins argues, if the public knows that facts do not speak for themselves, that disagreement among scientific experts is inevitable, that science is a human activity. In order to see the human character of science, we need to view the institution as though we were outsiders. *Changing Order* attempts to give us the necessary perspective.

Unfortunately, one must start this adventure with a heavy dose of philosophy. Fortunately, Collins's sense of humor makes the dose tolerable. He has us contemplate Wittgenstein's views of rules by playing a game called "Awkward Student." A joke about an Indian elephant illustrates the central questions of artificial intelligence. We approach the problem of replication as mice who have commissioned the Earth as a computer. The message is heavy, but the reading is just light enough to get most of us through to chapter 3. Once there, we are likely to stay the course.

Chapters 3, 4, and 5 report case studies that forcefully illustrate Collins's central points. They are rich in the details of scientific practice and make good reading. The dramatic saga of a TEA laser (transversely excited atmospheric-pressure CO_2 laser) calls into question the common picture of nature as "orderly and cooperatively passive," yielding truth in response to experiment. Instead, the case shows, the production of facts is the only available indicator of when an experiment has worked. Collins draws the conclusion that knowledge is not produced algorithmically.

The lack of independent criteria for "successful" experimentation results in what Collins calls "experimenter's regress." The criterion for successful procedure is fact, and the criterion for fact is successful procedure. "Experimental work can only be used as a test [of the validity of a knowledge claim] if some way is found to break into the circle," Collins writes, and illustrates the point with the controversy over gravitational radiation. The specific criterion that breaks into the circle will vary from case to case, but the development of consensus around the successful criterion is always a social process, not a mere exercise in logic. The third case, experiments in the paranormal, again shows "why and how the test of replication fails to work efficiently in disputed areas" (the only areas, Collins claims, where replication is ever used as a test).

The cases establish the plausibility of Collins's general claims, which are presented in chapter 5. A postscript spells out their implications for the politics of science. The algorithmic model of science encourages the view that method alone produces scientific knowledge. A mantle of infallibility becomes the basis for public trust and support for science. This view, Collins argues, is dangerous, since every instance of public disagreement over "the scientific facts" erodes the aura of infallibility. As an alternative, Collins proposes the enculturational model, the model the book explicates and illustrates. In this view, the locus of knowledge is not method but the community of expert practitioners. Scientists are seen as the best available consultants on a variety of matters rather than as infallible authorities.

The first model allows the citizen only two responses to science: awe or rejection. The second allows for a different kind of respect and forces the public to recognize the lack of purely technical solutions to political, moral, and technological decisions. The latter view is thus safer, according to Collins. To ask too much of science is to risk a widespread disillusionment our times can ill afford.

The argument is worth considering. *Changing Order* presents the case for the enculturational model as effectively as other, longer and less concrete, volumes that share its viewpoint. For both reasons, the book is worth the effort of thought experiment it requires.

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Surface Science

Many-Body Phenomena at Surfaces. DAVID LANGRETH and HARRY SUHL, Eds. Academic Press, Orlando, Fla., 1984. xiv, 578 pp., illus. $39.50. From a workshop, Santa Barbara, Calif., July 1983.

The quest to understand the many-body problem has long been a driving force in physics. This problem refers not to the racy possibilities one might imagine but to phenomena associated with the behavior of many interacting particles; for example, the book under review is concerned with the behavior of electrons and ions in solids. Although we have precise knowledge of the elementary Coulomb force between any pair of particles, the behavior of many particles is complex, often exhibiting novel behavior in the limit of large numbers. This is particularly so for the ultra-slippery electrons in a metal, which move quickly to balance any change in their environment. The introduction of a surface makes these many-body effects particularly subtle. Yet it is at surfaces that processes of great technological interest such as chemical reactions and catalysis take place.

The book's six sections reflect the current state of work in the field, which varies from remarkable progress on, say, the theory of ground-state properties, to much semi-empiricism, for chemical and catalytic reactions. Not every major topic in surface many-body phenomena is covered, a notable missing example being surface electronic band structure calculations.

Section 1 is devoted to the current theoretical framework for ground-state properties, density functional theory. The inspiration of Kohn, Hohenberg, and Sham, this theory turns the full (insoluble) many-body problem into a tractable one-particle theory in which the electronic density (rather than the Schrödinger wave function) is the basic variable. All the complexity is cleanly buried in the effective potential in which the electrons move. Occasionally ideas in theoretical physics work as if by magic, and this theory strikes one as the work of a conjurer. To quote von Barth, "Almost as if by a stroke of luck, already the simplest possible approximation to the full theory—the predominantly used local-density (LD) approximation—gives remarkably accurate results in a variety of systems." The magic is just beginning to be understood, one can see from a paper by Perdew and Levy. However, as Langreth notes, every topic covered in his review of density functional theory (subtitled "From fact! to fantasy?") requires more work. Section 2 discusses the binding of atoms to surfaces. Lundqvist's paper reveals that substantial progress has been made on this difficult problem and makes the understated claim that some results "indicate a degree of convergence between theory and experiment." A remarkable finding is that the shape of the curve of binding energy for chemisorbed metal atoms is almost universal. Much of the progress here rests on density functional theory. If there is discontent it is with excitation energies, for which, as Jones points out, there are unacceptable deviations from experiment.

Section 3 is less specific. It concentrates on a variety of spectroscopic techniques that have evolved for experimental studies of surfaces. Many of the topics in this section are relevant to dynamic many-body phenomena at surfaces, which is the subject of part 4. The treatment of such intrinsically many-body processes as dissipation and inelastic loss has led to a number of sophisticated new theories. Some are perhaps unexpected; for example, the messy-sounding process of sputtering is now explained by an elegant theory developed by Lang. The short sections on reactions and catalysis seem to have been included primarily as a challenge, for these subjects are the real problems toward which the fundamental studies covered in the rest of the book are ultimately directed. Their solutions seem very far off.

The book succeeds in conveying the revolutionary progress that has been made in fundamental surface science, particularly over the past decade. Advances ranging from new theories to ultra-high–vacuum surface experiments have brought this about. The reader will welcome especially the pedagogical spirit of many of the reviews presented. These give an up-to-date survey of the literature and also serve to make this highly technical, high-tech field understandable.

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General Relativity

General Relativity and Gravitation. B. BERTOTTI, F. DE FELICE, and A. PASCOLINI, Eds. Reidel, Boston, 1984 (distributor, Kluwer, Hingham, Mass.). xvi, 517 pp. $69. Fundamental Theories of Physics. From a conference, Padua, Italy, July 1983.

Physicists and mathematicians working on general relativity convene every three years for an international conference that has been held in a succession of pleasant cities all over the world for the last 30 years. The tenth and most recent of these—"GR 10"—took place at the University of Padua, where Galileo once taught. More than 750 relativists from all over the world attended.

The book under consideration consists of the invited papers and the reports of the various workshops of GR 10. It is a rich source of information on current research in the four main divisions of the subject: classical relativity, relativistic astrophysics, experimental general relativity, and quantum gravity.

It begins with a paper on some aspects of classical black-hole theory, especially the interaction of incident gravitational waves with Schwarzschild and Kerr black holes, by S. Chandrasekhar (who later in 1983 won a Nobel prize in physics). In a report from the workshop on black holes, R. M. Wald describes other recent developments. Among these are the discovery of a second real-life candidate for a stellar black hole (this one in the Large Magellanic Cloud), progress in the thermodynamics of black holes, and work on the so-called cosmic censorship hypothesis (that there are no "naked" singularities), on which much of black-hole theory rests. In a related paper D. Christodoulou gives, from initial data, a complete analysis of the evolution under their own gravity of spherically symmetric dust clouds, which contains a counterexample to the censorship hypothesis. The reaction of the experts, that this counterexample, like some earlier ones, is too specialized, only emphasizes the need for a tighter formulation of the hypothesis.

The longest paper in the book (74 pages) is one by G. F. R. Ellis on relativistic cosmology. It contains a very careful assessment of the extent to which the observations—in principle and in fact—support the currently used model universes. It makes clear that there are still many open questions, among them questions about the relation of the local physics to the distant galaxies and the validity in a nonlinear theory like general relativity of the various "smoothing out" techniques applied in dealing mathematically with a very lumpy universe. It should be noted that the currently fashionable inflationary approach to early cosmology is not discussed much in this book.

In another major paper R. W. Hellings reports on the results of a computer analysis of a very large quantity of data concerning the solar system and relevant to general relativity. A great jump in accuracy over previously analyzed data was possible mainly because of the use of spacecraft, especially the landers on Mars. (The latter made it possible to model the Earth-Mars distance to ± 10 meters during their six-year period of operation.) The results now confirm (the post-Newtonian parameters of) Einstein's theory to an impressive accuracy of one-tenth of one percent. Evidently this was of central importance to all participants, though one told Helling, "Well, I'm not surprised." Helling answered, "You may be pleasantly surprised, if you wish, but you must always be surprised!" Further details on space experiments can be found in the report from the workshop on this subject.

Intensive work on the detection of gravitational waves incident on Earth is