and quantum gravity, quantization of the gravitational field, supergravity, twistors, and other aspects of quantum theory and gravity.

A key guiding factor in the development of unified theories of elementary particle interactions has been renormalizability in flat space-time. (In a renormalizable theory, the infinities can be eliminated by absorbing them into a finite number of observable constants, such as mass and charge, which are then assigned values based on observation.) Because space-time is actually curved the question naturally arises whether a theory that is renormalizable in flat space-time will also be renormalizable in curved space-time.

A fine review by N. D. Birrell addresses the question. The curvature of space-time gives rise to new infinities that depend on the state of the system. Consequently, those infinities cannot be absorbed in the usual way into constants. For a theory to be renormalizable in curved space-time, the state-dependent infinities must almost miraculously cancel one another. Long and difficult calculations have shown that that does indeed occur for certain interacting theories, such as that of a scalar field with quartic self interaction ($\lambda\phi^4$ theory) and (to one loop order) quantum electrodynamics. However, no general theorem has been proved concerning renormalizability in curved space-time, so that such renormalizability may serve to further narrow the class of acceptable theories.

The very consistency of quantum field theory in curved space-time is questioned by M. J. Duff. His main point is that field redefinitions that mix the gravitational field with other fields alter the predictions of curved space-time theories but not of theories in which the gravitational field is also quantized. Duff's criticisms are answered by T. W. B. Kibble and Birrell, who point out, among other things, that the gravitational metric naturally plays a preferred role in curved space-time theories because it is treated as an unquantized classical field. Therefore, it is not surprising that field redefinitions alter the theory. It certainly is not an internal inconsistency of quantum field theory in curved space-time.

Quantum field theory in curved space-time has led to a number of solid discoveries, such as that the expanding universe creates particles and that black holes create particles with a thermal spectrum, that have had a profound and lasting influence on our conception of the early universe and of the fundamental connection between thermodynamics, quantum theory, and general relativity. Connections between thermodynamics and quantum gravity are explored in papers by P. C. W. Davies, Sciama, R. M. Wald, and Penrose.

There is almost no doubt that a complete theory must include gravity within its quantum framework. In an important contribution, B. S. DeWitt, one of the pioneers of quantum gravity, develops a gauge invariant effective action that may allow one to compute the influence of quantum gravity on the possible formation or avoidance of the cosmological singularity. Using an effective action approach, J. B. Hartle reviews particle production and the dynamics of the early universe. Also of importance in the early universe is acausal propagation in quantum gravity, which is discussed by S. W. Hawking. The canonical approach to quantizing the gravitational field is comprehensively reviewed by K. Kuchař. Supergravity, a significant attempt to create a renormalizable quantum theory of gravity by imposing a symmetry that includes both fermions and bosons, is reviewed by Duff, P. van Nieuwenhuizen, S. Ferrara, and K. S. Stelle and P. C. West.

There are other significant contributions in the book, which space does not permit me to discuss. In summary, the volume surveys much of the current research in quantum gravity and is highly recommended to researchers and graduate students.

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Hurricanes

Tropical Cyclones. Their Evolution, Structure and Effects. RICHARD A. ANTHES. American Meteorological Society, Boston, 1982. xviii, 208 pp., illus. $40. Meteorological Monographs, vol. 19, no. 41.

Much of our early knowledge about hurricanes came from William Redfield, who deduced from just a few observations made in the Long Island Hurricane of 1821 that the storm was "in the form of a great whirlwind." He was followed by many other investigators who compiled small quantities of data from many sources and deduced much information about the structure and forecasting of these tropical cyclones.

It was not until the middle of the 20th century, however, that there was a great expansion in hurricane research. The development of radar and aircraft reconnaissance of hurricanes during World War II and the weather satellite in the 1960's provided tools to obtain detailed information about hurricanes and to obtain information more often and reliably. Prior to 1940 a forecaster who issued an advisory about a hurricane frequently lost most of the information needed for making forecasts as ships warned of the hurricane headed for safer waters. Hurricane disasters in 1954 and 1955 provided motivation for Congress to expand support of hurricane research, and our understanding of hurricane structure and energy processes soon doubled.

The development of the high-speed computer in the 1950's greatly facilitated theoretical investigations of the development, movement, and dissipation of the tropical cyclone. Efforts were soon started to simulate the development and forecast the movement of tropical cyclones with numerical models. The work of the experimentalists and that of the theoreticians complemented and supported each other and enabled the total research effort to advance much more rapidly.

This book summarizes the research from the time of Redfield until about 1980. It is not merely a summary, however. The author traces the development of our knowledge in each of the several areas, and he also summarizes present knowledge, analyzes the strong and weak points in our understanding, and suggests what can practically be accomplished in the future. This is done for the structure and life cycle of tropical cyclones, physical processes in tropical cyclones, simulation by numerical models, hurricane modification experiments and theory, interaction between ocean and atmosphere, and forecasting of the movement of the tropical cyclones. The section on oceanic response includes a thorough discussion of the forecasting of the storm surge associated with hurricanes, which is the cause of the most damage due to hurricanes along the coast.

For the research scientist this is an excellent book. Much of the information in the chapters on hurricane structure and forecasting would be understandable to the nonprofessional, and even in the chapters written for the professional the writing is so good and concise summaries are so frequently put in simple English that a person with a general scientific background would understand many of the points being made. Summaries and discussions of errors in hurricane forecasting would be valuable for anyone who has to make decisions about hurricane preparedness.

The list of references is relatively complete and very representative of the good tropical cyclone research reports published in the last 40 years. The illustrations are excellent and include many outstanding photographs of hurricanes and hurricane damage. For a first edition there are few errors.

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Mental Representations

Imagery. NED BLOCK, Ed. MIT Press, Cambridge, Mass., 1981. viii, 262 pp., illus. Cloth, $15; paper, $7.50. A Bradford Book.

The role of imagery in mental life has for centuries been a recurrent topic of debate. Over the past decade the controversy has become especially heated, fueled by resurgent scientific interest in human cognition. The roots of disagreement are readily apparent. Most people will attest to their awareness of percept-like mental experiences, often visual, such as an image of the Statue of Liberty. They may claim to form such images in the process of performing certain cognitive tasks, such as deciding which of the statue's hands holds a torch. But such compelling introspections run head-on into a basis for rational skepticism: the notion that people have "pictures in their heads" immediately seems either conceptually incoherent or factually absurd. The imagery controversy, which has permeated both cognitive psychology and philosophy, has been a struggle toward a reconciliation of introspection with rational analysis.

This volume includes eight papers (most of them reprinted) that discuss the nature and function of mental imagery, with an introduction by Block. Both philosophers and psychologists are represented, and the collection intersperses attempts at conceptual clarification of the imagery concept with relevant psychological research and theory. Block's introduction provides a useful overview and sets the stage for the issues that pervade the later chapters. In particular, Block points out a variety of "false issues" that can easily confuse discussions of imagery. The debate between the "pictorialists" (who claim images have depictive properties) and the "descriptionalists" (who claim images are essentially propositional descriptions) is not about whether images *are* pictures, but about whether they are *like* pictures in relevant respects. The debate largely centers, in fact, on the question of what respects should be taken as relevant. Other issues that Block identifies as misleading include the questions of whether images exist (in some sense, of course they do), whether they are epiphenomenal, whether imagery is similar to perception, and whether images are "photographic." All of these questions, misleading or not, are discussed in the chapters that follow.

The two leading proponents of the "pictorialist" position represented in the volume are Jerry Fodor (on the philosophical side) and Stephen Kosslyn (on the psychological side). As the selection by Fodor (from his 1975 book, *The Language of Thought*) makes clear, the term "pictorialist" is itself rather misleading. No one believes that people always think in picture-like images or anything of the sort. Fodor presents classical arguments refuting both the possibility that thought can be identified with imagery and the view that "looking like" is either a sufficient or a necessary condition for referring. However, on the basis of a variety of psychological evidence, he favors the modest view that "images under descriptions" constitute a type of mental representation with depictive properties that people use to perform certain cognitive tasks (such as visual matching).

Kosslyn has two chapters in the volume. The first (coauthored with Steven Pinker, George Smith, and Steven Schwartz) is primarily a review of his empirical evidence that visual images have inherently spatial properties. The second presents his theory of imagery in more detail. Kosslyn's theory, which has been embodied in a computer-simulation model, is founded on a technologically updated version of the traditional picture metaphor: visual images are viewed as analogous to displays on a cathode ray tube. Like Fodor, Kosslyn subscribes to the position that imagery is but one form of internal representation, albeit one with distinctive properties. Kosslyn claims only that images can be constructed and maintained in active memory, allowing for the possibility that long-term memory is fundamentally descriptive in its mode of representation.

Daniel Dennett and Zenon Pylyshyn play the role of "descriptionalists" (or "iconophobes," to use Dennett's playful term). The first of two chapters by Dennett, which was originally published in 1969, serves mainly to illustrate the extent to which the imagery debate has subsequently been clarified. The position he attacks is clearly that of a straw man; Fodor's chapter rebuts Dennett's major points, and Dennett himself acknowledges in a new postscript that his conclusion was "rash and overstated" (p. 59). His second contribution is a much more conservative—indeed, admirably neutral—attempt to establish a definitional framework for the scientific investigation of mental imagery.

Pylyshyn's brand of iconophobia centers on two major points. The first is a proposal that imagery, if it is based on an analog mental medium, should prove to be "cognitively impenetrable"—in essence, impervious to influences of the meaning of that which is being represented. The second is a more empirical claim, that various phenomena often taken as evidence for an analog medium (for example, apparent "mental rotation") actually reflect subjects' "tacit knowledge" of physics and perception. Kosslyn, replying to Pylyshyn's points, argues that the criterion of cognitive impenetrability has little value in the absence of a careful stage analysis of cognitive tasks. While acknowledging the danger that imagery tasks may sometimes be influenced by tacit knowledge and other demand characteristics of experiments, he reviews a variety of evidence for depictive properties of imagery that is not easily explained by such extraneous factors.

Robert Schwartz provides a chapter that addresses perhaps the deepest question raised in the imagery debate—how do images represent? This question leads directly to one yet broader—what is symbolization? Schwartz points out the vagueness of the superficially plausible view that images represent by virtue of some "resemblance" to that which is being represented. He also makes it clear how difficult it is to differentiate among representational modes, suggesting there may not be one or two, but many forms of mental representation. The criteria that have been suggested to define an imaginal mode, he argues, are at best imperfectly correlated. Schwartz's cautionary critique suggests the directions in which the imagery debate is likely to continue.

This collection is somewhat narrow in its range of contributors; its focus is very much in Cambridge. In particular, it would have benefited from a paper by Roger Shepard, whose research and theoretical views surface repeatedly in various chapters. His work on mental rotation is introduced in a secondhand fashion in a chapter by Roger Brown and Richard Herrnstein drawn from their introductory psychology textbook. In a note following his introduction, Block offers an explanation for Shepard's ex-