Synopsis

The following brief summaries, arranged here alphabetically by author, provide an introduction to each of the papers in this volume.

1. *Allan Franklin, Right or Wrong.* **Robert Ackermann.** Franklin and Pickering agree that scientists in an experimental sequence, like the one to be discussed here, choose to accept certain experiments and their results as crucial, but disagree as to whether such choice can be justified in terms of an on-line estimate of evidential reliability. This paper suggests that it is possible to define a position between Franklin's Bayesian objectivism and Pickering's social constructivism. This position depends on considering the sequence of improvement in material technique and instrumentation as more important than any measure of reliability determined merely from such factors as evidential spread in relevant sequences, a factor that neither Franklin nor Pickering takes sufficiently into account.

2. *The Evolution of Scientific Lineages.* **Michael Bradie.** The fundamental dialectic of *Science as a Process* is the interaction between two narrative levels. At one level, the book is a historical narrative of one aspect of one ongoing problem in systematics. At the second level, Hull presents a theoretical model of the scientific process which draws heavily on invoked similarities between biological and scientific change. I first situate the model as one alternative among several which loosely fit under the umbrella of 'evolutionary epistemologies.' Second, I explore one of the implications of Hull's model, namely, that insofar as scientific theories are [parts of] "conceptual lineages," they are "conceptual individuals."

3. *Form and Order in Evolutionary Biology: Stuart Kauffman's Transformation of Theoretical Biology.* **Richard M. Burian and Robert C. Richardson.** The formal framework of Kauffman (1991) depicts the constraints of self-organization on the evolution of complex systems and the relation of self-organization to selection. We discuss his treatment of 'generic constraints' as sources of order (section 2) and the relation between adaptation and organization (section 3). We then raise a number of issues, including the role of adaptation in explaining order (section 4) and the limitations of formal approaches in explaining the distinctively biological (section 5). The principal question we pose is the relation of generic constraints on evolution to more specific local constraints, imposed, for example, by the characteristic materials out of which organisms are constructed, the accidental features characteristic of the Bauplan of a lineage, and the local vicissitudes of adaptation. We offer no answer to this large question.

4. *The Unimportance of Semantics.* **Richard Creath.** Philosophers often divide Carnap's work into syntactic, semantic, and later periods, but this disguises the importance of his early syntactical writing. In *Logical Syntax* Carnap is a thoroughgoing conventionalist and pragmatist. Once we see that, it is easier to see as well that these views were retained throughout the rest of his life, that the breaks between periods are not as important as the continuities, and that our understanding of such Carnapian notions as analyticity and probability needs reevaluation.

5. *Conventionalism and the Origins of the Inertial Frame Concept.* **Robert DiSalle.** This paper examines methodological issues that arose in the course of the development of the inertial frame concept in classical mechanics. In particular it examines the origins and motivations of the view that the equivalence of inertial frames leads to a kind of conventionalism. It begins by comparing the independent versions of the idea found in J. Thomson (1884) and L. Lange (1885); it then compares Lange's conventionalist claims with traditional geometrical conventionalism. It concludes by examining some implications for contemporary philosophy of space and time.

6. *Reasoning from Phenomena: Lessons from Newton.* **Jon Dorling.** I argue that Newtonian-style deduction-from-the-phenomena arguments should only carry conviction when they yield unexpectedly simple conclusions. That in that case they do establish higher rational probabilities for the theories they lead to than for any known or easily constructible rival theories. However I deny that such deductive justifications yield high absolute rational probabilities, and argue that the history of physics suggests that there are always other not-yet-known simpler theories with higher rational probabilities on all the original evidence, and that these later turn out closer to the truth. My analyses rely on the modern Solomonoff-Levin solution to the problem of constructing a mathematically and philosophically acceptable inductive logic.

7. *Do Mutants Have to be Slain, or Do They Die of Natural Causes?: The Cause of Atomic Parity Violation Experiments.* **Allan Franklin.** In this paper I will reexamine the history of the early experiments on atomic parity violation, presenting both Pickering's interpretation and an alternative explanation of my own. I argue that, contrary to Pickering, there were good reasons for the decision of the physics community. I will also explore some of the differences between my view of science and that proposed by the "strong programme" or social constructivist view in the sociology of science.

8. *Some Twists in the Cognitive Turn.* **Steve Fuller.** I argue that the recent "cognitive turn" in the philosophy of science does not challenge nearly as much of traditional philosophy of science as it proponents have claimed. However, the turn has forced philosophers to embody such hallowed abstractions as knowledge, theories, rationality, and concepts in flesh-and-blood human thinkers. While I welcome this newfound ontological awareness, I criticize four "mistaken identities" committed by two representative cognitivists, Howard Margolis and Ronald Giere. Generally speaking, the misidentifications turn on a fundamental naivete about the social dimension of thought.

9. *Belief Revision and Relevance.* **Peter Gärdenfors.** A general criterion for the theory of belief revision is that when we revise a state of belief by a sentence A, as much of the old information as possible should be retained in the revised state of belief. The motivating idea in this paper is that if a belief B is irrelevant to A, then B should still be believed in the revised state. The problem is that the traditional definition of statistical relevance suffers from some serious shortcomings and cannot be used as a tool for defining belief revision processes. In particular, the traditional definition violates the requirement that if A is irrelevant to C and B is irrelevant to C, then A&B is irrelevant to C. In order to circumvent these drawbacks, I develop an amended notion of relevance which has the desired properties. On the basis of the new definition, I outline how it can be used to simplify a construction of a belief revision method.

10. *I. Dynamical Reduction Theories: Changing Quantum Theory so the Statevector Represents Reality.* **GianCarlo Ghirardi and Philip Pearle.** The propositions, that what we see around us is real and that reality should be represented by the statevector, conflict with quantum theory. In quantum theory, the statevector can readily become a sum of states of comparable norm, each state representing a different reality. In this paper we present the Continuous Spontaneous Localization (CSL) theory, in which a modified Schrodinger equation, while scarcely affecting the dynamics of a microscopic system, rapidly "reduces" the statevector of a macroscopic system to a state appropriate for representing individual reality.

11. *II. Elements of Physical Reality, Nonlocality and Stochasticity in Relativistic Dynamical Reduction Models.* **GianCarlo Ghirardi and Philip Pearle.** The prob-

lem of getting a relativistic generalization of the CSL dynamical reduction model, which has been presented in part I, is discussed. In so doing we have the opportunity to introduce the idea of a stochastically invariant theory. The theoretical model we present, that satisfies this kind of invariance requirement, offers us the possibility to reconsider, from a new point of view, some conceptually relevant issues such as non-locality, the legitimacy of attributing elements of physical reality to physical systems and the problem of establishing causal relations between physical events.

12. *Implications of the Cognitive Sciences for the Philosophy of Science.* **Ronald N. Giere.** Does recent work in the cognitive sciences have any implications for theories or methods employed within the philosophy of science itself? It does if one takes a naturalistic approach in which understanding the nature of representations or judgments of representational success in science requires reference to the cognitive capacities or activities of individual scientists. Here I comment on recent contributions from three areas of the cognitive sciences represented respectively by Paul Churchland's neuro-computational perspective, Nancy Nersessian's cognitive-historical approach, and Paul Thagard's computational philosophy of science. The main general conclusion is that we need to replace traditional linguistic notions of representation in science.

13. *Material Models in Biology.* **James R. Griesemer.** Propositions alone are not constitutive of science. But is the "non-propositional" side of science theoretically superfluous: must philosophy of science consider it in order to adequately account for science? I explore the boundary between the propositional and non-propositional sides of biological theory, drawing on three cases: Grinnell's remnant models of faunas, Wright's path analysis, and Weismannism's role in the generalization of evolutionary theory. I propose a picture of material model-building in biology in which manipulated systems of material objects function as theoretical models. In each of the cases, material systems such as diagrams play important generative as well as presentational roles.

14. *Problematic Objects between Mathematics and Mechanics.* **Emily R. Grosholz.** The existence of mathematical objects may be explained in terms of their occurrence in problems. Especially interesting problems arise at the overlap of domains, and the items that intervene in them are hybrids sharing the characteristics of both domains in an ambiguous way. Euclid's geometry, and Leibniz' work at the intersection of geometry, algebra and mechanics in the late seventeenth century, provide instructive examples of such problems and items. The complex and yet still formal unity of these items calls into question certain tenets of Resnik's structuralism, and of the reductive projects of the logicists.

15. *Elementarity and Anti-Matter in Contemporary Physics: Comments on Michael D. Resnik's "Between Mathematics and Physics".* **Susan C. Hale.** I point out that conceptions of particles as mathematical, or quasi mathematical, entities have a longer history than Resnik notices. I argue that Resnik's attack on the distinction between mathematical and physical entities is not deep enough. The crucial problem for this distinction finds its locus in the numerical indeterminacy of elementary particles. This problem, traced by Heisenberg, emerges from the discovery of antimatter.

16. *Newton's Classic Deductions From Phenomena.* **William Harper.** I take Newton's arguments to inverse square centripetal forces from Kepler's harmonic and areal laws to be classic deductions from phenomena. I argue that the theorems backing up these inferences establish systematic dependencies that make the phenomena carry the objective information that the propositions inferred from them hold. A review of the data supporting Kepler's laws indicates that these phenomena are Whewellian colli-

gations—generalizations corresponding to the selection of a best fitting curve for an open-ended body of data. I argue that the information theoretic features of Newton's corrections of the Keplerian phenomena to account for perturbations introduced by universal gravitation show that these corrections do not undercut the inferences from the Keplerian phenomena. Finally, I suggest that all of Newton's impressive applications of Universal gravitation to account for motion phenomena show an attempt to deliver explanations that share these salient features of his classic deductions from phenomena.

17. *Philosophical Interpretations of Relativity Theory: 1910-1930.* **Klaus Hentschel.** The paper (given in the section on "Recent work in the History of Philosophy of Science) discusses the method and some of the results of the doctoral dissertation on philosophical interpretations of Einstein's special and general theories of relativity, submitted to the Dept. for History of Science, Univ. of Hamburg, in 1989, also published by Birkhauser, Basel, in 1990. It is claimed that many of the gross oversimplifications, misunderstandings and misinterpretations occurring in more than 2500 texts about the theories of relativity written by scientists, philosophers, and laymen contemporary to Einstein can in fact serve as a clue to a better understanding of the general process by which philosophical interpretations are formed. Another very important source for answering the question of how misinterpretations are formed are hitherto unpublished documents in the estates of physicists and philosophers of that time, including apart from Einstein himself: Bergson, Bridgman, Carnap, Cassirer, Metz, Meyerson, Petzoldt, Reichenbach, Schlick and Vaihinger.

18. *Conceptual Evolution: A Response.* **David L. Hull.** Each of the commentators on my *Science as a Process* has emphasized a different part of my book. Mishler concentrates on the relevant biology, Koertge expands upon the sociological mechanism I propose, while Bradie discusses biological and conceptual lineages as historical entities. I respond to these comments and criticisms, emphasizing the roles played by sequences of ancestor-descendant tokens in replication and ecological types in interaction. Hence, selection results from the alternation of genealogical tokens with ecological types in both biological and conceptual evolution.

19. *Computer Simulations.* **Paul Humphreys.** This article provides a survey of some of the reasons why computational approaches have become a permanent addition to the set of scientific methods. The reasons for this require us to represent the relation between theories and their applications in a different way than do the traditional logical accounts extant in the philosophical literature. A working definition of computer simulations is provided and some properties of simulations are explored by considering an example from quantum chemistry.

20. *Determinism in Deterministic Chaos.* **Roger Jones.** John Earman's *A Primer on Determinism* treats the doctrine of Laplacian determinism by a careful look at a considerable variety of physical theories. This paper enriches Earman's discussion of chaos theory by considering in some detail the analysis of dripping faucets due to Robert Shaw. Shaw's analysis exhibits in a nice way some of the techniques used in chaos theory and gives a feel for research in this area. The paper concentrates on the tension between the determinism inherent in any description involving differential equations and the in-practice (any practice) unpredictability resulting from the extreme sensitivity to initial conditions of the non-linear differential equations characteristic of chaos theory.

21. *The Sciences of Complexity and "Origins of Order".* **Stuart A. Kauffman.** This article discusses my book, *Origins of Order: Self Organization and Selection in Evolution*, in the context of the emerging sciences of complexity. *Origins*, due out of Oxford University Press in early 1992, attempts to lay out a broadened theory of evo-

lution based on the marriage of unexpected and powerful properties of self organization which arises in complex systems, properties which may underlie the origin of life itself and the emergence of order in ontogeny, and the continuing action of natural selection. The three major themes are: 1) that such self organized properties lie to hand for selection's further molding; 2) hence that the order we see is not due to selection alone, but in part reflects the order selection has always acted upon; 3) and finally that the marriage of natural order and natural selection may inevitably lead living entitites to a novel organized state, lying on the edge between order and chaos, as the inevitable evolutionary attractor of selection for the capacity to adapt.

22. *The Function of Credit in Hull's Evolutionary Model of Science.* **Noretta Koertge.** This paper first argues that evolutionary models of conceptual development which are patterned on Darwinian selection are unlikely to solve the demarcation problem. The persistence of myths shows that in most social environments unfalsifiable ideas are more likely to survive than ones which can be subjected to empirical scrutiny. I then analyze Hull's claims about how the credit system operates in science and conclude with him that it can perform a surprising variety of functions. However I argue that the credit system must be constantly tempered by internalized norms which encapsulate the traditional ultimate aims of science.

23. *The Road Since Structure.* **Thomas S. Kuhn.** A highly condensed account of the author's present view of some philosophical problems unresolved in *The Structure of Scientific Revolutions.* The concept of incommensurability, now considerably developed, remains at center stage, but the evolutionary metaphor, introduced in the final pages of the book, now also plays a principal role.

24. *Giving up Certainties.* **Henry E. Kyburg, Jr.** One of the serious motivations for the development of non-monotonic logics is the fact that, however sure we may be of some set of facts, there can come a time at which at least some of them must be given up. A number of philosophical approaches have stemmed from the study of scientific inference, in which a law or theory, accepted on good evidence at one time, comes to be rejected on the basis of more evidence. These approaches are reviewed, and an alternative approach, whose key idea is the control of observational error for the purpose of predictive adequacy is developed.

25. *Computer Simulations, Idealizations and Approximations.* **Ronald Laymon.** It's uncontroversial that notions of idealization and approximation are central to understanding computer simulations and their rationale. What's not so clear is what exactly these notions come to. Two distinct forms of approximation will be distinguished and their features contrasted with those of idealizations. These distinctions will be refined and closely tied to computer simulations by means of Scott-Strachey denotational programming semantics. The use of this sort of semantics also provides a convenient format for argumentation in favor of several theses I shall propose concerning the role computer implemented approximations and idealizations play in fixing what the acceptance of an underlying scientific theory is or should be.

26. *Hidden Agendas: Knowledge and Verification.* **Joia Lewis.** A complete reading of the works of Moritz Schlick reveals an apparent vacillation between a preference for holistic, formalistic accounts of knowledge and a preference for atomist, foundational accounts. A clearer picture of Schlick's philosophical development emerges from an appreciation of what I consider to be two separate "agendas," each of them fully formed and present in his earliest writings. Schlick's conviction that the assumptions in each agenda were equally correct can explain a good deal about the construction of his mature theses and is, I believe, responsible for much of the criticism that his work has

received, both before and after his death in 1936. Making the two agendas explicit can also provide us with a better framework within which to judge Schlick's work. Finally, the story provides an instructive example of how one's firmest beliefs constrain and dictate one's choice of solutions and perhaps define the problems themselves.

27. *Allan Franklin's Transcendental Physics.* **Michael Lynch.** This paper was presented at a session on "Three views of experiment: Atomic parity violations," in which Allan Franklin's study of an episode in the recent history of particle physics was discussed and criticized. Franklin argues in favor of what he calls "the evidence model," a general claim to the effect that physicists' theory choices are based on valid experimental evidence. He contrasts his position to that of the social constructivists, who, according to him, insist that social and cognitive interests, and not the evidence, explains physicists' practical and theoretical judgments. My paper argues that Franklin miscasts the debate between experimental realism and social constructivism, because constructivists do not insist that evidence has no role whatsoever in experimental practice. My position draws lessons from Wittgenstein's later philosophy and ethnomethodological studies of scientific practices. The paper does not aim to support social constructivism against Franklin's arguments, so much as to suggest that the terms of the realist-constructivist debate provide a poor context for the examination of the temporal production of experiments and observations.

28. *Paradigms and Barriers.* **Howard Margolis.** In a forthcoming study I give an account of paradigm shifts as shifts in habits of mind. This paper summarizes the argument. Habits of mind, on this view, are what constitute a paradigm. Further, some particular habit of mind (the "barrier") is ordinarily critical for a Kuhnian revolution. A contrast is drawn between this view and the "gap" view that is ordinarily implicit in analysis of the nature of of paradigm shifts.

29. *Structuralism and Conceptual Change in Mathematics.* **Christopher Menzel.** I address Grosholz's critique of Resnik's mathematical structuralism and suggest that although Resnik's structuralism is not without its difficulties it survives Grosholz's attacks.

30. *Phylogenetic Analogies in the Conceptual Development of Science.* **Brent D. Mishler.** I address David Hull's theses about the process of science from the perspective of an evolutionary biologist, particularly emphasizing phylogenetic systematics (a.k.a. cladistics), an area that has figured prominently in Hull's work as a source of both sociological data and metatheory. The goal is to carefully explore analogies and disanalogies between scientific process and comparative biology. There do seem to be remarkable analogies (e.g., research groups as lineages, scientists as interactors in selection processes), indeed these lead to important insights that might not otherwise have been made, yet some possible analogies present novel problems: Are "memes" like genes or like traits? What is the nature of replication in science? It is argued that the primary need is for some rigorously worked-out case studies.

31. *Barriers and Models: Comments on Margolis and Giere.* **Nancy J. Nersessian.** Giere's assessment is that the cognitive sciences, especially cognitive psychology, have much to offer the philosophy of science as it attempts to develop theories of the growth, development, and change of scientific knowledge as human activities. Margolis produces a model of scientific change by drawing from recent work in the cognitive sciences and attempts to show how this model explains salient cases of conceptual change. While agreeing with Giere's assessment, I argue that Margolis provides the wrong model both for scientific change and for how the interaction between cognitive science and philosophy of science should proceed.

32. *Self Organization and Adaptation in Insect Societies.* **Robert E. Page, Jr. and Sandra D. Mitchell.** Division of labor and its associated phenomena have been viewed as prime examples of group-level adaptations. However, the adaptations are the result of the process of evolution by natural selection and thus require that groups of insects once existed and competed for reproduction, some of which had a heritable division of labor while others did not. We present models, based on those of Kauffman (1984) that demonstrate how division of labor may occur spontaneously among groups of mutually tolerant individuals. We propose that division of labor itself is not a product of natural selection but instead is a "typical" outcome of self organization.

33. *Reason Enough? More on Parity-Violation Experiments and Electroweak Gauge Theory.* **Andy Pickering.** I respond to Allan Franklin's critique of my account of the establishment of parity-violating neutral-current effects in atomic and high-energy physics as an instance of a more general 'rationalist' attack on 'constructivist' understandings of science. I argue that constructivism does not entail the denial of 'reason' in science, but I note that there are typically too many 'reasons' to be found for 'reason' to count as an explanation of why science changes as it does. I show, first, that there were many 'reasonable' but different ways of reasoning about the field of evidence at issue in this episode and, second, that Franklin's articulation of how theory-choice should proceed on the basis of evidence implies a vicious conservatism which is fortunately not to be found in the history of science.

34. *Between Mathematics and Physics.* **Michael D. Resnik.** Nothing has been more central philosophy of mathematics than the distinction between mathematical and physical objects. Yet consideration of quantum particles shows the inadequacy of the popular spacetime and causal characterizations of the distinction. It also raises problems for an assumption used recently by Field, Hellman and Horgan, namely, that the mathematical realm is metaphysically independent of the physical one.

35. *Computer Simulation in the Physical Sciences.* **Fritz Rohrlich.** Computer simulation is shown to be philosophically interesting because it introduces a qualitatively new methodology for theory construction in science different from the conventional two components of "theory" and "experiment and/or observation". This component is "experimentation with theoretical models." Two examples from the physical sciences are presented for the purpose of demonstration but it is claimed that the biological and social sciences permit similar theoretical model experiments. Furthermore, computer simulation permits theoretical models for the evolution of physical systems which use cellular automata rather than differential equations as their syntax. The great advantages of the former are indicated.

36. *Are Pictures Really Necessary? The Case of Sewell Wright's "Adaptive Landscapes".* **Michael Ruse.** Philosophical analyses of science tend to ignore illustrations, implicitly regarding them as theoretically dispensible. If challenged, it is suggested that such neglect is justifiable, because the use of illustrations only leads to faulty reasoning, and thus is the mark of bad or inadequate science. I take as an example one of the most famous illustrations in the history of evolutionary biology, and argue that the philosophers' scorn is without foundation. I take my conclusions to be support for a naturalistic approach to philosophy.

37. *Designation and Convention: A Chapter of Early Logical Empiricism.* **T.A. Ryckman.** An examination of Carnap's *Aufbau* in the context of Schlick's *Allgemeine Erkenntnislehre* of ten years earlier, suggests that Carnap's focus there on the sign-relation (Zeichenbeziehung) is an effort to retrieve a verificationist account of the meaning of individual scientific statements from the abyss of meaning-holism entailed by

Schlick's proposal that scientific concepts be implicitly defined. The *Aufbau*'s antipodal aspects, its reductive phenomenalism and quasi-Kantian concern with the constitution of objectivity, are seen as complementary moments of the marriage of empiricism and a new emphasis on scientific concepts as "free creations of the human mind".

38. *The Appraisal of Theories: Kuhn Meets Bayes.* **Wesley C. Salmon.** This paper claims that adoption of Bayes's theorem as the schema for the appraisal of scientific theories can greatly reduce the distance between Kuhnians and logical empiricists. It is argued that plausibility considerations, which Kuhn considered outside of the logic of science, can be construed as prior probabilities, which play an indispensable role in the logic of science. Problems concerning likelihoods, especially the likelihood on the "catchall," are also considered. Severe difficulties concerning the significance of this probability arise in the evaluation of individual theories, but they can be avoided by restricting our judgments to comparative assessments of competing theories.

39. *Desiderata for a Modified Quantum Dynamics.* **Abner Shimony.** If quantum mechanics is interpreted as an objective, complete, physical theory, applying to macroscopic as well as microscopic systems, then the linearity of quantum dynamics gives rise to the measurement problem and related problems, which cannot be solved without modifying the dynamics. Eight desiderata are proposed for a reasonable modified theory. They favor a stochastic modification rather than a deterministic non-linear one, but the spontaneous localization theories of Ghirardi et al. and Pearle are criticized. The intermittent fluorescence of a trapped atom irradiated by two laser beams suggests a stochastic theory in which the locus of stochasticity is interaction between a material system and the electromagnetic vacuum.

40. *How Free are Initial Conditions?* **Lawrence Sklar.** Those who think of some aspects of the world as "physically necessary" usually think of this kind of necessity as being confined to the general law of nature, initial conditions being "contingent." Tachyon theory and general relativity provide independent but related reasons for thinking that some initial states are, however, "impossible." And statistical mechanics seems to lead us to conclude that some initial conditions are, if not impossible, "highly improbable." We are then, led from these aspects of physics to wonder if initial conditions are always "freely specifiable" and in the domain of physical contingency.

41. *"From the Phenomena of Motions to the Forces of Nature": Hypothesis or Deduction?* **Howard Stein.** This paper examines Newton's argument from the phenomena to the law of universal gravitation—especially the question how such a result could have been obtained from the evidential base on which that argument rests. Its thesis is that the crucial step was a certain application of the third law of motion—one that could only be justified by appeal to the consequences of the resulting theory; and that the general concept of interaction embodied in Newton's use of the third law most probably evolved in the course of the very investigation that led to this theory.

42. *Mapping Ecologists' Ecologies of Knowledge.* **Peter J. Taylor.** Ecologists grapple with complex, changing situations. Historians, sociologists and philosophers studying the construction of science likewise attempt to account for (or discount) a wide variety of influences making up the scientists' "ecologies of knowledge." This paper introduces a graphic methodology, mapping, designed to assist researchers at both levels—in science and in science studies—to work with the complexity of their material. By analyzing the implications and limitations of mapping, I aim to contribute to an ecological approach to the philosophy of science.

43. *Law Along the Frontier: Differential Equations and Their Boundary Conditions.* **Mark Wilson.** Physicists often allow the "laws" of a discipline, formulated as partial differential equations, to be disobeyed along various surfaces, arrayed along the boundary and inside the medium under study. What kinds of considerations permit these lapses in the applicability of the equations? This paper surveys a variety of answers found in the physical literature.

44. *Taming the Dimensions—Visualizations in Science.* **William C. Wimsatt.** The role of pictures and visual modes of presentation of data in science is a topic of increasing interest to workers in artificial intelligence, problem solving, and scientists in all fields who must deal with large quantities of complex multidimensional data. Drawing on studies of animal motion, aerodynamics, morphological transformations, the history of linkage mapping, and the analysis of deterministic chaos, I focus on the strengths and limitations of our visual system, the analysis of problems particularly suited to visualization—the analysis of similarities and differences between complex objects, and problems making conjoint use of information from several complex images.

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