

dynamics an average approximation of ideally precise molecular interactions. Mechanical reversibility and thermodynamic irreversibility were reconciled by treating the latter as an average gross approximation of the former. The "law of large numbers" was there to guarantee that microscopic shocks, spreading out uniformly in time and space the distribution of local dynamic variables associated with single molecules, inevitably ended up with less ordered (and therefore more "probable") macroscopic states.

These bridging laws, however welcome they were to the physicist and the chemist, seemed to baffle the hope of reducing the principles of biological organization to a mere appendage of "ordinary" physicochemical principles. If the spontaneous trend of inanimate matter points toward increasing uniformity and the intimate mixing of everything with everything else, how can one account for the progressive complexity and finer differentiation shown by biological evolution? The entropy law of spontaneous increasing disorder seems to fly in the face of the laws of evolution as ascertained by the biologist. Each living system is, however, an "open" system from the thermodynamic point of view. It is, moreover, a system that is "far from equilibrium," as recent works by Ilya Prigogine and Manfred Eigen have emphasized. Biological order is maintained at the expense of a constant incoming flow of matter and energy. Even though Helmholtz had declared in his momentous paper of 1847, "On the Conservation of Energy," that "the question . . . whether the combustion and metamorphosis of the substances which serve as nutriment generate a quantity of heat equal to that given out by animals . . . can be approximately answered in the affirmative,"¹⁰ the mutual compatibility between thermodynamic laws and biological phenomena has remained an open problem for a long time. Two opposing ontological commitments face each other and keep offering their mutually incompatible credentials to provide the explanation of how life is possible. These opposing themes are best visualized by the *crystal* on the one side (invariance of specific structures) and the *flame* on the other (constancy of external forms in spite of relentless internal agitation). The search for a *third* way out of this dilemma (structure or process, inborn patterns or self-reorganization) has constituted for more than a century the common trait of otherwise distinct and sometimes contrasting research programs. For the sake of simplicity, let us confine our archeology to the research programs extending uninterruptedly until today, in fact until this very debate between Piaget and Chomsky.

The "crystal" theme, first raised to the level of a plausible scientific world model or archetype by René-Just Haüy in 1784,¹¹ entails at least two far-reaching assumptions, namely: (1) that specific visible patterns are always, at least in principle, traceable to the microscopic world, where they correspond to specific molecular patterns, and (2) that the crystalline (or molecular) underworld can only change according to its own rules. There is no symmetry of determinism between the two worlds; the microscopic dictates its laws to the macroscopic. August Weismann, the father of the germ-plasm theory, was already categorical on this point: "As in the growing crystal the single molecules cannot become joined together at pleasure, but only in a fixed manner, so are the parts of an organism governed in their respective distribution . . . In the case of a crystal it has not occurred to anybody to ascribe the harmonious disposition of the parts to a teleological power; why then should we assume such a force in the organism, and thus discontinue the attempt, which has already been commenced, to refer to its natural causes that harmony of parts which is here certainly present and equally conformable to law?"¹² Weismann's discovery of chromosomes and the subsequent identification of these microstructures as the material carriers of hereditary traits are the main stepping-stones toward contemporary molecular genetics. Another far-reaching assumption, to which we will return in some detail when examining the Chomskian hard core, is the dichotomy first established by Johannsen between *genotype* and *phenotype*, thereby separating physically, logically, and operationally the ideal stock of potentialities relative to a species (genetic competence) from its multifarious, context-dependent expression in terms of individual patterns (actual performance).

In 1943 Erwin Schroedinger, with almost prophetic insight, advanced the hypothesis that genes are "aperiodic crystals," and in ten years, thanks to Watson and Crick, the structure of such aperiodic crystals was decoded. This is, in rough summary, the scientific research program of molecular biology, whose hard core forms the background of Jacob's remarks (see Chapter 2) and of Danchin's "critical note" concerning phenocopy (see Appendix A).

Schroedinger's lectures of 1943 are, however, in retrospect, the Y-junction from which a quite different research program also developed.¹³ Crystals are fine, but, so this new story goes, there is much more, physically speaking, to life than crystal structures alone can account for. There is statistical disorder, which constantly surrounds the crystal patterns, and vibra-

tional, rotational, and twisting random motions, which are revealed by closer inspection at the atomic level. After all, it had long been recognized that mutations arising from within the genetic structure are part and parcel of the evolution of living beings. Schrodinger was thus compelled to make the important consideration that life "feeds on" both order (the aperiodic crystals and other regular molecular patterns) and disorder (random atomic vibrations and collisions). This apparently untendentious remark was to be grafted, within the space of a few years, onto the freshly developed hard core of Shannon's information theory, and especially to the notion of messages flowing through a channel perturbed by parasitic noise. In 1959 Léon Brillouin added to the research program of information theory a new ontological commitment: the identity between information and entropy, as previously defined by thermodynamics (with a minus algebraic sign, hence the term "neg-entropy"). The dispersed elements then click together, and the ontological framework is reassessed under the guidance of the following assumption: living systems are, basically, informational devices, their genes being a *source* of messages, their different processing mechanisms a *channel*, and the mature individual the *receiver*. The bio-informational hard core and the Piagetian guiding commitment (*hypothèse directrice*) are based on the belief that life is a gigantic information flow mediating (or regulating) the transition of the "entire universe" from a less organized initial state to increasingly more organized steady states. Cognitive acts (human cognitive acts in particular) are the most efficient mediators of such information flow, the privileged catalysts of a cascade of transfers of order from one portion of the universe to the next.

There is a major puzzle to be solved, however, if this ontological commitment is to be protected from the devious assaults of rational criticism and carefully collected evidence. How can order *increase* other than by execution of a predetermined ad hoc program? How can the notion of spontaneity and strict autonomy of development be matched with that of an increase in degree of complexity? Molecular biology (that is, the contemporary edition of the crystal outlook) can accommodate these conflicting injunctions thanks to the concept of genetic programs or genomes. Order can increase and structure can become more and more complex because the organism is equipped with a constructive plan, distinct from its material expressions and containing from the very start the "envelope" of its possible realizations. Noise (that is, random fluctuations) can hinder or

facilitate the process of growth, divert or block the possible pathways of development, but it can never dictate their geometry. There is no transfer of structure from the macro-environment to the micro-archive.

Heinz von Foerster, whose ideas are now enthusiastically endorsed by Piaget, makes a different assumption, of which the manifold implications have not yet been fully examined.¹⁴ He contends that random fluctuations can indeed *create* order and not only reveal (as in a photographic processing) the underlying constructive plan. When a highly complex system is submitted to all sorts of indignities, such as shaking, twisting, and scrambling, its component parts are amenable to interlocking with one another and materializing into a new system instantiating unprecedented ordered patterns. The order that thus arises from noise is "potentially encoded" in the local organization of the component parts, but *nowhere else*, that is, in no global blueprint applying to the system *as a whole*. Coherence and order at a global level arise from local interactions only.

A rigorous treatment of the "order from fluctuations" principle has been developed, albeit from a different standpoint and at the physicochemical level, by Prigogine through his theory of dissipative structures. Both approaches fit very well into Piaget's more general conception of "autoregulation" and seem to provide even harder physicomathematical justifications for his cognitive-psychological hard core. It is reasonable to anticipate that any assailant of the Piagetian hard core (leaving aside local incursions into the protective belts of his "psychology" proper) will have to take arms simultaneously against a host of related conceptions. Ontological commitments tend to form clusters, and although some may be more resistant than others, or bear on separate domains of reality, the history of science proves that local wounds heal quickly when the surrounding tissue is unaffected. In my opinion von Foerster's principle is far from being flawless, and Prigogine's theory may well also support a "selectivist" explanation of cognitive processes, as opposed to an "instructivist" or a "constructivist" one. But it would be out of place to delve any deeper into these technical questions here. Before moving on to the main topic of this debate, we must analyze the Chomskian hard core.

THE CHOMSKIAN HARD CORE

The overpowering "theme," in Holton's terms, of the Chomskian scientific research program in linguistics is undoubtedly the classical notion of *rationalism*. An allegiance to Descartes

and Leibniz is recurrent throughout all of Chomsky's major writings. Its affinities for what I have labeled the "crystal" program are manifold, as I will attempt to show.¹⁵ The focal assumption of the rationalist program, as will be made clear in the present debate, can be expressed as follows: the environment per se has no structure, or at least none that is *directly* assimilable by the organism. All laws of order, whether they are biological, cognitive, or linguistic, come from inside, and order is *imposed* upon the perceptual world, not *derived* from it. These laws of order are assumed to be species-specific, invariant over time and across individuals and cultures. The positive heuristics of all such programs, Kant's included, is to characterize in depth and in detail the internal structure of a universal subject (the "ideal speaker" of Chomsky) through adequate abstractions from empirical givens.

Abstraction is *not*, however, generalization through progressive extension, and data are *not* brute facts observed by an "innocent eye" (in Gombrich's terms). The rationalist positive heuristic is grounded on an awareness that theory is involved from the outset in the sorting out of *relevant* observation from sheer noise (from which no order is expected to arise). In the present debate, Chomsky and Fodor frequently emphasize the notion of relevance within their rationalist approach (see Chapters 3, 5, 15, 16). There is no denial, in Chomsky's and Fodor's sometimes extreme positions, that there is much more to language and cognition (for example, culture, social interactions, affectivity) than the nativist approach alone can account for, but the demarcation is still very sharp between what in all these contexts is *pertinent to the problem at hand* (the structure of the universal subject) and what is irretrievably *alien* to it.

In addition to the commitment to universal inborn structures and to theory-determined abstractions, rationalism is also committed to a "compartment theory" of the human mind. The internal structure of the ideal speaker, or of the universal cognitive-perceptive subject, not only has to be specific in its totality, but also has to be decomposable into equally specific substructures, amenable to separate investigations. The rationalist commitment entails a kind of lumping strategy through which domains are demarcated and rendered as little as possible "conversant" with one another. Such abstract models, to be of any scientific value, have to be general enough to give a grasp of a truly universal subject, but detailed enough to become informative and falsifiable by experiment. They can, moreover, afford to be local (that is, relative to a well-defined subdomain)

and very exacting in terms of the innate properties that one is led to attribute to the organism. It is one thing to allow for some rudimentary, poorly articulated *inborn potentialities* (not even the extreme behaviorists have rejected that), and quite another to postulate very complex and highly *specific* innate structures that are *actually available* to the organism. This is what Putnam calls the "messy miracle" of human nature (see Chapter 14)—to which Chomsky and Fodor respond with a characteristic "rationalist" statement, revealing their underlying negative heuristic: "Why should it be otherwise?" Since beavers show highly specific inborn patterns of behavior to build dams, and spiders to build webs, why should not humans, who are by evidence endowed with much more complex brains, not have inborn linguistic structures as complicated as the "specified subject condition" or "bound anaphora?" (See Chapters 1 and 15.) The rationalist ontological commitment is very transparent here.

Is it out of mere coincidence—or worse, just through free association of words—that the "crystal" theme was turned into a scientific research program by Häy's "law of rational indexes?" Do the two notions of "rationality" have anything in common? I think they do, and I will proceed to explain why. This will not be an idle exercise in scientific archeology; on the contrary, I see no better and quicker way to attune the reader to the far-reaching resonances of this debate. We have seen above, in broad outline, why the Piagetian program departs from the molecular biological one. It is useful to see now why the Chomskian program comes so close to it.

Häy is committed to "the idea, so satisfying and so true, that in general nature tends to uniformity and simplicity."¹⁶ This is the crystal theme in its pure and lofty form. It becomes a more sanguine commitment, however, when it descends to earth, to the mineral world: "The ratios between the dimensions of the limiting forms possess this last property [simplicity] in a remarkable way."¹⁷ But the crystal conception of orderly forms, the living ones included, had more compelling hypotheses in its conceptual tool kit than just "simplicity"; it had *specificity* (of patterns), *directiveness* (of forces), *stability* (of local structures), *numerability* (of a finite set of combinatorial build-ups), and, finally, the all-important notion of pattern *revelation* (as opposed to infinite creation of forms by the environment). We will see in the debate that today, using more technologically sophisticated terms, this concept is visualized by "photographic development" (see Chapter 4) or, to borrow from molecular biology, by the concept of "template." The German botanist

Schleiden, with the less sophisticated language available to him in 1850, wrote that "the matter of the crystal exists in the liquid, already formed, and it suffices to withdraw the solvent in order to force its appearance in fixed form."¹⁸ The chemical statement is directly translatable into Chomsky's photographic concepts of "exposure" (to linguistic data) and of "development." After all, photographic development is literally a process of light-induced crystallization. The hard core of both crystallographic "rationality" and generative linguistics is that "all structure comes from within." Environment *reveals* this structure; it does not *imprint* its own patterns on the system. It should by now be evident why the confrontation between constructivism and innatism runs, all through this book, precisely on this crucial dividing line.

POSITIVE HEURISTIC AND PROTECTIVE BELTS

The continuum connecting the "crystal" program in the natural sciences and the Chomskian program in linguistics subsists also at the level of the *positive heuristic*. According to Lakatos, "the negative heuristic specifies the 'hard core' of the program which is 'irrefutable' by the methodological decision of its protagonists; the positive heuristic consists of a partially articulated set of suggestions or hints on how to change, develop the 'refutable variants' of the research program, how to modify, sophisticate the 'refutable protective belt.'"¹⁹ Ontological commitments pertaining to the negative heuristic consist of *negative expectations* (there is no structure in the environment per se, there is no transfer of structure from the outside to the inside, and so on); those pertaining to a positive heuristic consist of *selective conditional expectations*. Assuming, as all tenants of the "crystal" negative heuristic do, that no laws of order are supplemented by the environment, the positive heuristic entails the consequential assumption that structures (1) are internal to the organism, (2) are species-specific, (3) are contingent (logic *alone*, unaided by experiment, cannot account for what they are), and (4) preexist to any orderly interaction with the outer world.

This is, however, a rather approximative set of statements, which need to be amended and spelled out more precisely. What Chomsky (or a "crystal theorist" in general) will say is rather that the structure of the environment is *not* the intrinsic structure of the organism, nor can the former be incorporated *as such* into the latter. The intrinsic structure of the organism determines what structured features of the environment will be transferred within. ("Transfer" has to be understood here in terms of

a decoding or mapping function, and not as literally an incorporation or a direct embodiment.) Thus if one is interested in the nature of the organism rather than in the order in the environment, one will focus attention on *intrinsic determinants*, such as the built-in properties of the visual cortex (which permit certain structures from the environment to affect the steady state attained in a certain way), the genotype, or universal grammar (see my remarks at the beginning of Chapter 4).

The "protective belt" of the "crystal" program is made up of precise hypotheses on how patterns are selected, by the varying parameters of the environment, out of a finite numberable *set of possible configurations*. In structural chemistry (and biochemistry), the sets of possible conformations are generated through groups of transformations (symmetry groups, translational groups, rotational groups, and so forth) applying to ideal elementary units or "cells." Each observed pattern instantiates a *specific ordered string* of such transformations. The chemical nature of the atoms and the specification of environmental parameters (temperature, pressure, ionic force of the solvent) determine which string is selected in each case out of the set of all possible ones. Forms, in Schleiden's terms, "preexist" in the liquid and are "forced to materialize" under appropriate conditions. The positive heuristic of the Chomskian program is expressed through commitments that resemble very closely those of Schleiden. Chomsky specifies that a "rationalist" account of language acquisition is based on "the assumption that various formal and substantive universals are intrinsic properties of the language acquisition system, these providing a schema that is applied to data and that determines in a highly restricted way the general form and, in part, even the substantive features of the grammar that may emerge upon presentation of appropriate data."²⁰ Data exert no "formative" action on the ideal speaker-listener. There is, according to Chomsky, no assimilation or interiorization by the subject of structures subsisting independently outside. Data have, in the rationalist approach, a sort of "triggering" action. Chomsky is explicit on this point: "In part [primary linguistic] data determine to which of the possible languages the language learner is being exposed . . . but such data may play an entirely different role as well; namely, certain kinds of data and experience may be required in order to set the language-acquisition device into operation, although they may not affect the manner of its functioning in the least."²¹ In the present volume, Chomsky and Fodor call this the "ignition key" hypothesis (see Chapter 7): the engine is switched on by the igni-

tion key, but the structure of the ignition device bears no resemblance to the structure of the combustion engine. Their positive heuristic is dominated by this assumption.

Every rationalist program, at least since Leibniz, is committed to a search for the set of formal rules governing the world of possible structures. Access to this hidden world can only be secured by theoretical insight and steel-hard reasoning, not by simple enumeration of actually observed patterns. Catalogues are of no use unless they are collected, *from the start*, under the guidance of a nontrivial falsifiable and theoretical model. Information only informs if there is a theory behind it. "There is, first of all, the question of how one is to obtain information about the speaker-hearer's competence, about his knowledge of the language. Like most facts of interest and importance, this is neither presented for direct observation nor extractable from data by inductive procedures of any known sort."²²

Chomsky's linguistic program, in contrast to the classical rationalist program in philosophy, is a scientific research program and is thus committed to painstaking work on relevant data that can provide tests for the conjectures embedded in the protective belt. But even though facts are irretrievably enmeshed with theory, linguistics and cognitive psychology are not pure mathematics, as Chomsky points out in the present debate (Chapter 2), nor should there continue to be endless brooding on the consequences of a theoretical assumption (see Chapter 12). Observation must have its say, and observation is sometimes messy, perturbed by noise, and not rigorously reproducible, especially in the human sciences. From this comes the need to separate, on logical and operational grounds, the universe of possible organizations from actually observable organized patterns. The latter *have to be seen* (in a rationalist positive heuristic) as *instantiations* of the former. The partition of the scientific "object" into two related but distinct realms is cardinal to the rationalist program (and in particular to its naturalistic version that we have called the "crystal" program). Such a partition has ontological consequences, since the sets of possible forms and the laws governing them are conceived as objectively *inherent* to the domains under study, and not just as useful figments of imagination existing solely in the heads of scientists. Part II of this volume delves deeply into this question. (Are grammars properties of the brain of the speaker or properties of the language?)

Crystallographers introduced concepts such as crystal force (von Leonhard), formative processes and formative powers

(Ungar), and valence and coordination power, ending up, after Schrodinger, with the notion of informational content associated to the aperiodicity of biological crystals (proteins and nucleic acids). Cytologists produced the working hypothesis of a functional distinction between germen and soma (Weismann), and geneticists endorsed the subtler distinction between genotype and phenotype (Johanssen), the inner logic of which dictates the remarks made at this meeting by Jacob, Changeux, and Danchin (see Chapters 2 and 8 and Appendix A). Chomsky introduces a similar distinction between *competence* and *performance*, respectively defined as "the speaker-hearer's knowledge of his language" and "the actual use of language in concrete situations."²³ How closely the competence/performance and the genotype/phenotype distinctions relate to each other will appear in the course of this debate.²⁴ It is worth noting, however, that Premack (see Chapter 7) opens a crucial problem when he asks whether the concept of competence should include the actual propensity to *use* the competence—a problem that, as Monod reminds us (Chapter 7), was already present in Descartes.²⁵ The ongoing refinement of models in generative linguistics has led to important reassessments within this partition and to movable frontiers between "linguistic levels" (syntactic, semantic, pragmatic) since Chomsky first stated their constitutive principles.²⁶ These are, however, the typical refinements of a "protective belt," and they need not concern us here. Reverting back to the unchanged (and, as Lakatos anticipates, intrinsically irrefutable) hard core, we see that there are immediate consequences of the competence/performance dichotomy. Universal grammar is, by definition, invariant across individuals and across languages; it is ultimately to be accounted for in terms of species-specific neuronal circuits. Chomsky often reminds us that this biological "reduction" is possible *in principle*, though not as yet accomplished in fact (see Chapters 2 and 4). More precisely, what Chomsky suggests is that it is a very satisfying first approximation to make the assumption that the initial state of the language faculty is invariant or species-specific (that is, to abstract away from such individual or cultural differences as may exist). Of course, in a more complete analysis the real competence attained in the steady state will show differences; there is a competence for a given language (French, English, Japanese, and so on). There are also individual differences within a given language. Nor is it claimed that such a characterization of the initial stage of the language faculty (presumably genetically coded) is literally invariant, but rather that one can properly abstract away

from variation to determine the basic species character of the organism, just as one abstracts away from individual differences when one tries to find out what it is that makes humans grow arms instead of wings (see Chapter 2). Competence is an abstract property ascribed to the "steady state" attained by the ideal speaker-listener in the course of time, as a result of neurological development and of a suitable schedule of exposure to "relevant" linguistic data. Apart from gross neurological insults or extreme deprivations of sensory input (such as the *enfants sauvages* severed from all contacts with a community of speakers), the steady state is invariably attained. Constructing a plausible (though specific, informationally rich, and refutable) model of this steady state is the central task of the "universal grammar." Since the concept of a steady state is a substantial part of the Chomskian hard core, it requires a bit of "thematic" analysis.

The heuristic power of the steady state is equal to that of Piaget's "autoregulation," but it points toward a different chain of ontological commitments. Once again I assume there are two possible levels of commitment, a weaker one, certainly sound but of no momentum, and a stronger one, relevant but subject to questioning. Every physical system can be characterized as "being in" a state of some sort, specifiable if need be by a set of values attached to its constitutive parameters. The first concept of state presupposes no more (but no less) than the accessibility of the system to measurement (even approximate) and sufficient identification through descriptive statements (a state has to be different from another state). This is the weaker commitment. Chomsky specifies that linguistic analysis must aim at gaining insight into "the tacit knowledge of the native speaker" through "introspective evidence." The steady state implies, therefore, accessibility to measurement (of a particular kind) and identification in terms of describable properties of *that* state. We will, moreover, read in this volume (Chapter 4) that a hypothetical alternative model of the idealized speaker that allows the system to draw inferences of a different kind from those demonstrably drawn by real human speakers when exposed to a given set of data (for instance, inferring structure-independent rules as "good" rules for forming the interrogative) is a "bad" model; it cannot work because it presupposes a different and *incompatible* underlying steady state.

States are, therefore, attributed to systems that are accessible to "measurement" (rules of transformation imply quantitative assessments) and are describable through statements identify-

ing state A as distinct from state B. But Chomsky goes further than that, for he assumes that some computations or "inferences" are, as we will see, incompatible with the supposed structure of the system. Thus, states are not only distinguishable and susceptible to being ordered (hierarchically, sequentially, chronologically) but also are subject to eliminative induction, in terms of compatibility and incompatibility. The stronger commitment, as indeed was to be expected, is the one that Chomsky endorses. States are conceived as deterministic "regimes" of functioning, susceptible to factorial analysis. Steady states, in the conjectural ascription that Chomsky makes of them to the ideal speaker-listener, are, characteristically, *computational abilities* of a specific kind.

Such an ontological commitment entails the identity between linguistic representations (in the mind of the speaker-listener) and computations in a suitable "medium." The far-reaching consequences of an a priori identification between mental states and computations are exhaustively analyzed by Jerry Fodor in his book *The Language of Thought*²⁷ (see also his presentation in Chapter 6 and his "Reply to Putnam" in Part II of this volume). The "theme" of computation appears to be deeply entrenched in the hard core of generative linguistics and cognitive psychology. Fodor is categorical on this point: "The only psychological models of cognitive processes that seem even remotely plausible represent such processes as computational." Such a commitment, in turn, entails the assumption that mental states (and in particular those that are involved in the processing of linguistic data) are orderly sequences of microstates characterized by finite differences between local parameters. In principle, at least, neurobiologists in the twenty-first century will make it their business to specify in terms of neuronal switches what these microstates consist of. The steady state can therefore be assimilated to a multipurpose master program endowed with vast arrays of optional subroutines running in sequence or in parallel, whose different stages of accomplishment correspond to specific microstates of the brain machinery. But here the positive heuristic faces some serious problems. Microstates of this kind are ideal states, on precisely the same unsafe footing that made Boltzmann's program of statistical mechanics crumble under the brunt of quantum mechanics. The microstates of statistical mechanics turned out to be *illegitimate* idealizations of macroscopic dynamic states. Quantum laws in principle forbid extrapolating to the ideal case of microscopic systems the measurements that can be carried out at a macroscopic

level. The notion of state is *not* an invariant across physical orders of magnitude. Therefore, some ontological assumptions that are constitutive of the Chomskian hard core may, in the long run, prove untenable. To dispel all immediate concerns, it is safe to assume that linguists and psychologists will not have to grapple with these niceties for a long time to come, if ever. Nonetheless, a thematic analysis is forced to contemplate such prospective predicaments. The notion of state is, after all, less innocent than it appears at first sight.

STEADY STATES, FLAMES, AND CRYSTALS

The adjective *steady*, unassuming as it may appear at first sight, actually opens a thematic bridge toward the tenets of the "other" school of thought, that is, the "order-from-noise" conception of life and cognition. This shift is probably unintentional on the Chomskian side and is certainly, at the present macroscopic stage, noncommittal. Steady states are typical of *dynamic equilibria*, whereas stable states are typical of *static equilibria*. Chomsky is right in describing the standard computational "regime" of his ideal subjects as steady rather than stable. A billiard ball coming to rest at the bottom of a basin, or crystals being formed under progressive saturation of a solution, constitute canonical examples of stable equilibrium states. In dynamic processes, whenever a constant turnover of matter is geared to a uniform flow of transformable energy, steady states may appear. The canonical example is the flame of a candle in an environment devoid of turbulence.

Historically and epistemologically, the archetype of the crystal and the archetype of the flame as "models" of life have always been opposed to each other. Modern biology has successfully avoided the horns of that dilemma by committing itself to the model of a "tape-recorded program." Biomolecular crystals are tightly packed containers of information (the DNA template, the messenger RNA, the catalytic site of enzymes, and so on) whereby dynamic equilibria are produced and controlled in the living organism. The concept of *information* and the ensuing concept of *processing* (that is, computing) fill the gap, in biology as well as in cognitive psychology, between the hard core of the "orthodox" crystal program and the more dynamically oriented requirements that have to be met if new fields of inquiry are to bend under its dictum. The "bound information" program is, essentially, a more sophisticated makeup of the crystal program, having appointed Schroedinger and Crick-Watson as chief cosmeticians.

Flows of information are processed in the brain by standard programs whose compiler is, in ultimate analysis, the genetic program itself. It is precisely at this delicate joint that constructivists and proponents of order-from-noise drive their wedge. In fact, they assume it to be an integral part of their job to find adequate explanations of how any program whatsoever can be assembled in the first place. Following this line of argumentation, if an innatist explanation holds for man, it must on the same grounds hold for bacteria and viruses (see Piaget's remarks in Chapters 1 and 2 and my editorial notes at the end of Chapters 1 and 6). One therefore invariably comes to the point where a program must have materialized out of something that was *not* a program. But this, Chomsky and Fodor retort, is none of their concern—linguists and psychologists already have a difficult enough time explaining the gross properties of a particular species without getting involved in the parochial *biochemical* problem of how life originated. Up to this point, the quibble is about "what interests me" or "what is an integral part of my job as psychologist or linguist." No philosophical argument will ever be of help in matters of taste. Innatists retort, rather cogently, that to try to determine the characteristics of, say, the visual cortex of the cat or for some future biologist to try to find out in some detail how the genetic program for humans gives rise to brain lateralization and how it shapes brain connectivity is by no means sweeping the dust under the rug. They contend that the study of the nature and unfolding of the genetic program is a study *on a very different level* from the investigation of how this genetic endowment reached its present state in the species. They cannot see any contradiction inherent in this methodological stand. The tenants of the order-from-noise principle purport, however, to demonstrate that no explanation in terms of preset programs is *logically* sound unless one gives at least a hint of how programs are assembled at their source. Sweeping the dust under the rug (that is, pretending not to bother with the origins of programs) does not improve, in the long run, the cleanliness of the innatist clubroom. The problem will have to be met head on one day or another. Self-organization, so their story goes, has to precede, logically and factually, program-directed regulation. The "self" prefix stands for "out of non-organization" or, in von Foerster's terms, "from noise." There is no program dictating the shape and the constancy of the flame, but nonetheless, whenever the external conditions are fulfilled, a flame will materialize and will go on burning with always exactly the same pattern of bright, dark, and dimly

luminous zones. A steady state can fathom its inner necessity nowhere else than in the disordered shocks of particles, governed by their *local* microscopic structures. Piaget's positive heuristic is dominated by the assumption that there can be "necessity without innateness"; in other words, that structures can form, reproduce, and subsist without a program dictating all their possible assemblies *as a whole* and *from the very beginning*. Global order can arise from local "myopic" orders. The steady state is the cornerstone of such a conception.

Is the notion of steady state a sort of "traffic circle" where Piaget's constructivism and Chomsky's rationalist innatism, at least momentarily, converge? It is for the reader to answer this question. The debate supplies ample food for thought. Piaget and Changeux, as well as Papert, Cell  rier, and Inhelder, opt for a possible compromise. Chomsky and Fodor insist that their conceptions diverge from those of the Geneva school on practically all assumptions of some methodological importance. In my editorial remarks I will draw the reader's attention to these problems in more detail. For the time being, I will close by mentioning that the themes "local versus global" or "centered versus acentered" or "structure versus process" are as yet the "soft" core of future biological programs. The destiny of the "bound information" program of contemporary molecular biology will depend on the ultimate success of these themes in explaining vast bodies of experimental data. For the moment, this program is in all respects by far the best that has been envisaged by science to account for man's own constitutive principles as a living being. As to language and learning, about which this introduction has intentionally said very little, the programs are stated by Piaget and Chomsky themselves. After all, that is precisely what the book is about.